TWENTIETH ANNUAL REPORT

OF THE

Quebec Society for the Protection of Plants

1927-1928

Supplement to the report of the Minister of Agriculture

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QUEBEC
1928

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To the Honourable J. E. Caron, M.P.P.,

Minister of Agriculture,

Quebec.

Sir:—

I have the honour to present herewith the twentieth Annual Report of the Quebec Society for the Protection of Plants, containing the proceedings of the winter meeting of the Society, which was held at Macdonald College, Ste. Anne de Bellevue, Que., on Wednesday, April 18th, 1928.

Included are the papers that were read, and the reports of the officers of the Society.

I have the honour to be,

Sir,

Your obedient servant,

E. Melville DuPorte,

Secretary-Treasurer.

Macdonald College, Quebec.

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Whitehead, W. E.	Macdonald College, Que.
Willey, Dr. A.	58, Metcalfe St., Montreal.
Winn, A. F.	32, Spingfield Ave., Westmount.

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Rev. Father Superior, Ste. Anne de la Pocatière.
A. Gibson, Esq., Dominion Entomologist, Ottawa.
Hon. Minister of Crown Lands and Forests, Quebec.

ANNUAL MEETING

The twentieth annual meeting of the Quebec Society for the Protection of Plants was held in the Biology building, Macdonald College, on Wednesday, April 18th, 1928. There were forty two persons in attendance.

The business meeting was called to order at 1.30 p.m. The minutes of the last meeting were read and approved. The financial statement was read and approved.

The following officers were elected for 1928-1930.

President:—C. E. Petch, Esq., Entomological Laboratory, Que.
Vice-President:—Prof. Georges Maheux, Dept. of Agriculture, Quebec.
Secretary-Treasurer:—Dr. E. Melville DuPorte, Macdonald College.
Assistant-Secretary:—Omer Caron, Esq., Dept. of Agriculture, Quebec.
Directors:—Rev. Father Leopold D. Sc. Ag., La Trappe, Que.
Dr. W. H. Brittain, Macdonald College, Que.
Prof. J. G. Coulson, Macdonald College, Que.
H. N. Racicot, Esq., Laboratory of Plant Pathology Ste Anne de la Pocatiere, Que.
Prof. E. Campagna, School of Agriculture, Ste Anne de la Pocatiere, Que.
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Delegate to the Royal Society of Canada:—The President.
Delegates to the Ontario Entomological Society:—Rev. Father Leopold, Dr. E. Melville DuPorte, Dr. W. H. Brittain.
Delegates to the Canadian Branch of the American Phytopathological Society:—Rev. Father Leopold, Prof. J. G. Goulson, Mr O. Caron, Prof. E. Campagna.
Delegate to the International Congress of Entomology: Dr. DuPorte.

Father Leopold presented a brief report of the last meeting of the Entomological Society of Ontario to which he was a delegate from this society.

The following new members were nominated and elected: Dr. D. L. Bailey, Dr. Berkeley, Rev. Father Robitaille, Dr. A. Pepin, Messrs Moise Gagnon, Nazaire Parent, Jos. I. Beaulne, J. B. Maltais, F. Godbout, L. Daviault.

An innovation was introduced this year in the holding of a symposium on Recent Advances in our Knowledge of Insect Pests and Plant Diseases. Those leading in this discussion were:

C. E. Petch, Orchard Insects in Quebec.

H. G. Crawford, Forecasting Insect Outbreaks.

J. J. de Gryse, Aeroplane Dusting in the Control of Forest Insects.

W. H. Brittain, Insecticides.

H. N. Racicot, Virus Diseases.

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The symposium proved to be very successful, and it is proposed in future meetings to make the symposium with the discussion arising therefrom, the principal item of the program.

Following the symposium a number of papers were presented by members of the society. These papers are published in this report.

In the evening Dr. D. L. Bailey, Professor of Plant Pathology in the University of Toronto, formerly Senior Pathologist in charge of Rust Research in Western Canada, gave the invitation address. He discussed the problems involved in rust control investigation, and the progress which is being made in this work.

Following this most interesting address, Dr. H. Barton, Dean of the Faculty of Agriculture, McGill University, spoke briefly and enthusiastically in appreciation of Dr. Bailey's work and of the activities of the society.

At the conclusion of the meeting Professor Georges Maheux made the following resolution:

"That the visiting members of the Quebec Society for the Protection of Plants express to the authorities of Macdonald College their sincere thanks for the kindness and hospitality shown them during their visit."

FORECASTING OUTBREAKS OF THE PALE WESTERN CUTWORM AND ARMY CURWORM IN ALBERTA *

By H. L. Seamans, Entomological Laboratory, Lethbridge, Alta.

During the last several years, field crops in Alberta have suffered heavily from the pale western cutworm, *Porosagrotis orthogonia* Morr. and from the army cutworm, *Chorizagrotis auxiliaris* Grote. The pale western cutworm is largely an underground feeder, cutting plants so low that they seldom recover except under the most favorable conditions. Its habit of feeding below the soil surface makes it immune to practically all known direct artificial control measures, although infestation of the fields can be prevented by cultural practices. The army cutworm on the other hand feeds almost entirely above the surface of the ground and is readily controlled by the use of trap furrows and poisoned baits. The losses caused by this insect are largely due to the fact that outbreaks appear without warning and serious damage is done before the control measures can be put into effect.

The eggs of the pale western cutworm are laid during August and early September, but do not hatch until growth starts the following spring, usually about the first of May. The larvae, which do not migrate even when food is scarce, are usually mature the last week in June and pupate two or three inches below the soil surface. The moths, which begin to emerge early in August, are fully mature and ready to lay as soon as they appear. The maximum flight and oviposition occurs late in August and from then on dwindles rapidly. The eggs are laid in the top half inch of the soil and the female moth always chooses a location where the soil surface is soft or dusty, irrespective of the presence or absence of vegetation. Fields that are left entirely untouched during August and early September, so that a crust forms on the soil surface, are not suitable for oviposition and hence are free of infestation the following season. Fields of grain which are harvested during this period are almost sure of infestation the following year because the harvesting operations tend to keep the crust broken up and in ideal condition for oviposition.

Forecasting outbreaks of the pale western cutworm is based on the reaction of the larvae to soil moisture and its bearing upon parasitism. In a normal dry soil the larvae seldom come to the surface either to feed or move about. They are well insolated from most of their parasites and only rarely, when a larva feeds on the leaves of grain, may it become parasitized by swallowing an egg of one of the tachinids which oviposit upon the leaves of the food plants.

Whenever the soil is wet, however, the larvae come to the surface and feed on the upper portions of the plants. They are then likely to become parasitized

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* Contribution from the Division of Field Crop and Garden Insects, Entomological Branch, Department of Agriculture for Canada, Ottawa.

by species which oviposit upon leaves as well as by other species which lay their eggs directly on or in the cutworm. Thus it is that a season with sufficient rainfall to keep the larvae on the surface much of the time results not only in a greater number of cutworms being parasitized but in a marked increase in the numbers of the various species of parasites involved.

Field and laboratory studies have shown that a rainfall of one quarter of an inch is sufficient to bring the larvae to the surface of the soil where they remain until the soil has dried out enough to permit of cultivation. The number of days during May and June when the larvae must remain on the surface can be determined by the daily observation of the soil, or by a study of daily precipitation records and such days are considered as "wet" days. Having determined the number of "wet days" it is possible to forecast with some accuracy whether the insect will be abundant the next season or not. With results of the forecasts in mind the cultural practices to avoid infestation can then be put into effect for the coming year if necessary or entirely disregarded if no outbreak is to be feared.

A study of weather records and outbreaks in connection with larval development has shown that 15 "wet days" are sufficient almost to wipe out an outbreak. Less than 10 "wet days" result in a low parasitism of the larvae and a corresponding increase in the outbreak. The value of the forecasting lies in the fact that the farmer can adjust his cultural methods for certain fields which will be free of infestation just as he will know that other fields will be a total loss if seeded. He is also relieved of any worry and can cultivate as he pleases if the forecasting shows the outbreak to be at an end.

The army cutworm has an entirely different life-history from that of the pale western cutworm. The moths emerge in early June and after a short period of flight they aestivate during the hot weather of July and August in any place that will afford shelter. With the coming of cooler weather in late August, the moths resume activity. Oviposition lasts through September and often late into October. The eggs hatch in the fall and the larvae are about half grown when winter stops all activity; this commences again early in April. Being surface feeders the larvae are easily controlled by the use of poisoned bait or trap furrows, but their enormous numbers and their habit of migrating as they destroy the vegetation often cause severe losses before control measures can be put into effect. The larvae mature early in May and pupation takes place below the soil surface.

The serious damage caused by the army cutworm is almost entirely due to the suddenness of the outbreaks which catch the farmers unprepared. Great numbers of moths, however, in the fall are no indication of an outbreak the following season, and outbreaks rarely occur two years in succession.

Studies of the army cutworm both in the field and laboratory have shown that rainfall during the period of aestivation will destroy many of the moths which are hiding under clods and rubbish in the field. These studies have also

shown that moisture in quantity is essential to the successful hatching of the eggs and for the survival of the first stage larvae in the autumn. With these two conditions in mind a review of the meteorological records brought out the fact that years of heavy outbreaks were preceded by seasons with an abnormally dry July and a wet autumn. Such conditions allow many of the moths to survive the period of aestivation during July and early August and abundant moisture during late August, September and October makes possible the hatching of a high percentage of the eggs and for keeping the first stage larvae alive.

The average season in Alberta has over one and one-half inches of rain in July and less than four inches for the three months of August, September and October. The average season preceding army cutworm outbreaks has less than one inch of rain in July and over six inches during the next three months. The forecasting of outbreaks is based on the amount of rainfall during aestivation and the hatching of the eggs in the fall. A July with less than one and one-half inches of rainfall does not necessarily mean an outbreak the following season but indicates the possibility of some increase in numbers. The dry July, followed by over four and a half inches of rainfall during late August, September and October indicates a serious outbreak the next spring. Thus it is possible, by the first of November, to determine whether or not an outbreak is likely to occur and preparations for spring control work can be made accordingly.

RECENT ADVANCES IN INSECTICIDES

By W. H. Brittain

The term "recent" as applied to the subject under discussion, has quite a different meaning than when ordinarily used. Fifty years ago, from the standpoint of a student of human affairs, would be considered a very recent period, but if we went back that far in the history of the use of insecticides, we would reach a time when our practices on this continent had reached little beyond the point that they have today reached in China. Paris green, however, had been discovered as a remedy for potato beetles and in the eighties of the last century began to be used for a number of insects, though, previous to this time, certain materials such as tobacco decoctions, soaps and, in the late fifties, hellebore, had a certain restricted use. They were not, however, sufficiently effective, convenient nor economical to stimulate the great and rapid development that took place after the possibilities of fighting insects by means of chemicals was so clearly demonstrated by the use of Paris green. This material itself, though still largely used, does not hold the same relative position that it once did. Indeed it has been largely replaced in progressive communities by other materials, and almost the only uses for which we hear it officially recommended

today are as an ingredient in poison baits and for the destruction of mosquito larvae.

Lead arsenate came in answer to the demand for a chemical the use of which would not be attended with such dangers when applied to plants. First prepared in 1892 by Moulton, a chemist of the Gypsy Moth Commission, this chemical is still recommended to be used for a wider range of insects than probably any other insecticide. Its chemical stability and excellent physical qualities combined with its comparative safety to tender foliage account satisfactorily for its popularity.

Calcium arsenate came in answer to the demand for a cheaper arsenical. It was experimented with in 1912 by the U. S. Bureau of Entomology and was soon taken up by the manufacturers and, though receiving many setbacks, owing to the great variability and instability of the early product, it has had a rapidly increasing use. It has found its widest utility in the treatment of truck and market garden crops generally, and large quantities—thirty million pounds in 1924—are used in dusting cotton. It is not recommended for use on fruit trees and I know of only two official spray calendars where its use in composition with lime sulphur is recommended on apple trees, because of the dangers that are considered to attend its use. What may prove to be a valuable improvement over the calcium arsenates already available has recently been made by the Chemical Warfare Service of the United States. This special calcium arsenate is made by heating precipitated chalk and white arsenic (As_2O_3) in the presence of excess air at a temperature of 650 degrees C. The particles of this material are said to consist of an inert core of calcium carbonate covered with a coating of substantially 100% normal calcium arsenate. Prepared in the manner described a calcium arsenate containing only 20% arsenic as As_2O_5 is said to be (1) as toxic as the ordinary commercial brands containing 40%, (2) is harmless to the cotton plant and (3) can be manufactured at a cost far lower than the calcium arsenate now on the market.

A novel method of using arsenic was described by Dr. Howard as having been observed by him last summer (1927) in Czecho-Slovakia. Arsenic is incorporated in a sort of gigantic Roman candle. This, attached to a pole, is carried burning through the orchard and, operating on the principle of a wartime smoke screen, throws off a dense fog that settles down upon the trees.

Though apparently used to some extent before that time in certain proprietory preparations, the development of the use of the fluosilicates as insecticides has been only a matter of the past three years. They have been used with success against such insects as biting lice (Mallophaga) and against such insects as cockroaches. They have been used against the Mexican bean beetle, cotton boll weevil, striped cucumber beetles and blister beetles, and other Coleoptera. Sodium fluosilicate is the one most commonly employed and is ordinarily used mixed with hydrated lime. Since these materials owe their value as insecticides to their property of stimulating the "cleaning up habit of insects" these materials have been generally more successful as dusts than sprays.

The main advantages claimed for these materials as insecticides are (1) their relative low cost, (2) the fact that may act to some extent as contact as well as stomach poisons, (3) they are less toxic to the human species, and (4) their rapid action. Among the disadvantages noted have been (1) their poor physical properties, being heavy, of low covering and adhesive qualities, (2) their reputed toxicity to plants, especially the more soluble copper, zinc, copper and aluminium salts. It is claimed, however, that these disadvantageous properties have been overcome by the incorporation with sodium fluosilicate from 10% to 20% of colloidal silica. This additional sodium fluosilicate can be obtained as a by-product in the commercial manufacture of said phosphate, without additional apparatus and without alteration of the apparatus at present in use. The resulting product, containing 80% Na_2SiF_6, caused no damage to the cotton plant, killed the boll weevil more rapidly than commercial calcium arsenate, but was still below commercial calcium arsenate in ability to adhere to foliage.

A further and very important development in the insecticide factor was the development of a satisfactory commercial nicotine preparation. Crude decoctions of course were in use from very early times, but there was no hope in them for any important development. Marked progress was made with the first commercial extract, known as "Black Leaf Extract" put on the market about 1890. This was followed by other improved preparations of free nicotine and finally by the sulphate form in 1910. The development of a satisfactory contact insecticide of uniform composition, possessing a high degree of safety to the plant and compatible with other insecticides and fungicides for use on plants, was a great step in advance. At the present time solutions of free nicotine minus the objectionable features of some of the early preparations are used by florists for spraying in greenhouses or for vapourizing to kill aphids and other sucking insects; absorbed in special papers it may also be burned for the same purpose. The sulphate form, (usually containing 40% of actual nicotine) is the most widely used and still most generally useful of contact sprays and its high concentration and chemical stability facilitate storage.

During the past ten years so-called "nicotine dusts" have been developed to meet this growing demand for a contact poison in dust form. In most of the commercial preparations, nicotine sulphate is the active ingredient. Kaolin was first used as a "carrier" but this material was found to adsorb the material too completely and much work has been done to find a suitable "carrier" that would act as an "activator" for the nicotine sulphate ,since the value of the material depends upon the degree of concentration of nicotine fumes that can be secured at the time of application.For details of this work there is an extensive literature to which those interested may refer, but it may be said that lime is the most common carrier and, while it has been shown that there are considerable differences between different kinds and forms of lime with respect to their effects in causing a rapid evolution of nicotine gas, dolomite lime being much in favor, ordinary high calcium hydrated lime is much used and, under orchard

conditions, gives excellent results. Nicotine dusting is most advantageous for treating low growing crops like potatoes or turnips for aphids, where it is used in connection with a canvas trailer. It has also proven highly effective for large, active, sucking insects such as *Miridae*, that must be treated rapidly at certain critical periods.

One of the most interesting recent development in the use of nicotine, is its employment for destroying apple bud moth larvae just before they come out of their hibernacula. Another interesting fact, clearly brought out in Nova Scotia by Kelsall and his associates, has been the persistance with which nicotine sulphate remains adhering to the leaf, destroying as a stomach poison newly emerging larvae of the bud moth, sometimes several weeks after application.

In discussing recent developments in insecticides, little need be said regarding the lime sulphur wash, since there have been few new developments in this material since 1910, which, in economic entomology, may be regarded as a remote epoch. It may still be regarded as the standard scalicide for such pests as the San Jose and oyster shell scale, today its place has been taken to some extent by oil sprays. An advance in the safening of this material for use as a summer fungicide spray has been made by Kelsall, in the use of aluminium sulphate with this mixture.

Though oil emulsions have been used since the late seventies, and though various commercial miscible oils have been on the market since 1904, one of the features of the past four years has been the rapid increase in the use of lubricating oil emulsions, using soaps, calcium caseinate, Bordeaux etc., as the emulsifying agent. Work with this class of oils received a great stimulus following the work of Ackerman published in 1921, in which San Jose Scale was controlled more effectively than by the use of lime sulphur. Since then such materials have been widely used for the control of the eggs of the fruit leaf-roller. They have been used with success for a number of species of scale insects, for controlling the European red mite on fruit trees, for hibernated pear psylla adults, for the newly hatched stem mothers of certain species of aphids etc. Bordeaux oil emulsion is showing excellent promise as a remedy for the onion maggot.

All this has brought about a most intensive study of oils, their physical and chemical qualities, the factors that give them their value as insecticides and those that render them toxic to the plant. Though considerable progress has been made there is still much to be learned upon this question.

One would like to discourse on other interesting developments in contact insecticides, of which there are a considerable number. Of plant products other than nicotine, the product known as derris, being the powdered root of *Deguelia elliptica*, an oriental fish poison, has come into some prominence and its uses are increasing. The knowledge that many related plants show similar properties will doubtless give an impetus to further investigation with related species. Coal oil extracts of pyrethrum are proving valuable fly sprays. Oleoresins of this

material have been used successfully to destroy adult Japanese beetles, after they have been attracted by geraniol.

The development of hydrocyanic gas as an insecticide has been one of the most noted triumphs of economic entomology and it is one with which you are all familiar. It is only a matter of the last five years that calcium cyanide has been developed as a source of this gas. The amount of research that has been applied to the use of this material over this period has been impressive. Thanks to its property of forming the gas rather slowly in reaction with the atmospheric water vapour, it may be used for purposes for which this poison could not before be used. It has been used for citrus trees in nearly all countries where these trees are grown, for chinch bugs in Illinois and Missouri, as well as a soil fumigant for wire worms, as a fumigant for mills, green-houses, dwellings etc., in many countries, for scavenger termites in Africa and India and for burrowing rodents in all parts of the world.

Since Dean in 1911 demonstrated the value of dry heat as an insecticide against insects in mills etc., and its superiority over various fumigants ordinarily employed, there has been a great extension of the use of this on a large commercial scale.

Chlorpicrin is one of the war gases that has lately been adapted for the fumigation of mills. Ethyl ester of monochloracetic acid has more recently been found to have promise as a fumigant. The development of paradichlorbenzene as a treatment for peach borers and the use of corrosive sublimate for cabbage maggot represent distinct advances in economic entomological practices.

The foregoing represent a very few of the most important advances in insecticide practice. There are many other materials still in the experimental stage and others that are not yet discovered, that may very soon change the entire picture as we see it today, with that bewildering rapidity that we have all come to look for as the natural order of things in this particular field. A pressing need at present is for a cheap substitute for nicotine.

We are often warned against the danger of making predictions, but, I would like in closing to venture a prediction as to the future of economic entomology and to express the conviction that, while the biological control method, "cultural" methods and similar means at our disposal, will undoubtedly be exploited to a greater degree than ever before, the warfare against insects will remain as largely a chemical warfare. While it is gratifying for us to reflect that, in so many cases, the insecticidal use of various chemicals has been discovered or exploited first by entomologists rather than chemists, yet the need of a sounder training in chemistry for all out entomologists-in-training is of the utmost importance. Another thing to which we must give attention is the subject of insect physiology. It would be hard for any of us to conceive of a pharmacology not based upon a sound knowledge of human physiology. Yet many of us attempt to study the effect of various poisons upon insects with no knowledge whatever of insect physiology. We must also take cognizance of

plant physiology in our studies of insecticides. The physiological condition of the plant has often important bearing upon the effect of a material used upon such plant, whether it be injurious or harmless. Above all there is a pressing need of more exact methods in insecticidal investigations which, too often, in the past have been sadly lacking.

STUDIES ON THE ASSOCIATION OF CERTAIN PHYTOPATHOGENS

By J. E. Machacek, M. S. A.

Introduction.—

Association of plants is by no means a new subject for study, though so far reports dealing with association of phytopathogens have been comparatively rare, as a survey of the literature on the subject indicates. Most attention has evidently been turned to other branches of research.

Recently, during an extensive survey of storage rots at Macdonald College and vicinity, it has been observed by the writer that even though the rots were relatively abundant and many vegetables and fruits were attacked, the number of species of pathogenic organisms on a single specimen was very limited. It was only rarely that more than two species of these organisms were found at the same time on the same host. In advanced stages of the rots, the number of saprophytic species increased. Sometimes two or more wound parasites were found on different specimens in the same lot of host plants, but only in a few cases were they in intimite association. Association of parasites with saprophytes was much more common.

Large numbers of fungus spores are continually dispersed over exposed objects. It seems strange, therefore, that association of phytopathogens is not more general. It is by no means a rare occurrence to have several diseases present on the same plant, but they are seldom closely associated.

The importance of phytopathogenic association cannot be overestimated, for it is found frequently in nature. It is a well-known fact that cereal plants are rendered more susceptible, when already being hosts to various smuts, to the attacks of rust. Apples bearing lesions caused by the Scab fungus, *Venturia inaequalis*, may become rotted in storage by the Pink Rot fungus, *Cephalothecium roseum*. Other common associations include the following: potato tubers attacked by *Synchytrium endobioticum*, but later rotted by bacteria; tomato fruit attacked by *Cladosporium fulvum*, but the destructive rot being initiated later by *Botrytis sp.;* the rot of onion bulbs, caused by *Botrytis allii*, later followed by *Erwinia caratovora: Sclerotinia fructicola on apples*, later followed by *Penicillium expansum*. In most cases the primary invasion does not do very great

harm, but it is the secondary parasite which enters through the wounds caused by the primary parasite that causes the major part of the damage.

Object of Work:—

The purpose of this investigation is to study the association of certain phytopathogens on the host, and also to determine the physiological relationships of the associated organisms by cultural experiments.

Preliminary Considerations:—

The survey of storage rots brought out several problems dealing with the physiology of association. Among the prominent ones were following: cause of limitations of the number of pathogens in a rot; the reasons for the inhibition of growth of some of these organisms when associated with others; the reasons for the change in a rot type due to association of the causal organisms; the effect of the H-ion concentration, the effect of spore number of each organism; and, the effect of temperature.

Answering and clarifying questions involved in the above problems requires a great expenditure of time and labor, especially if the number of organisms associated in a culture is more than two. On account of the rapid increase in the complexity of the whole problem of association when many organisms were studied, the number of these was limited to six.

Materials:—

As phytopathogenic association was studied on the host as well as in culture media, large supplies of both healthy and diseased specimens of fruit and vegetables were required. Three main groups of rots were studied: those of the apple, the onion, and the tomato, In each case the two organisms concerned were able to cause a rot under nearly similar conditions, and so could be compared readily in their effect on the host, whether separate or in association.

When diseased specimens were needed for examination, only those which were partially rotted were selected. This was necessary in order to prevent needless isolation of saprophytic forms which could be found on the decayed host tissue. The presence of the saprophytes probably has considerable influence on the development and activities of the pathogens, but if the study of many pathogens and non pathogens in a certain type of rot was undertaken, the resultant mass of data would be too complicated for clear comprehension. Therefore, specimens which were rotted slightly, and which yielded only one or two pathogens were selected.

Healthy specimens of the same variety, same degree of maturity and the same size were used in the experiments. As all the experimental work dealt

with "wound parasites", it was necessary that all the specimens were as sound as possible. Small injuries to the epidermis often served as a means of entrance to the contaminating organism, and so during preliminary trials some specimens had to be discarded, for this, necessarily interfered with preparation of data. Therefore apples which were used for the study of apple rots were all hand-picked, graded and belonged to the varieties MacKintosh Red, Fameuse, and McMahon White. Similarly, three varieties of onions, Red Weathersfield, Yellow Globe, and Silverskin were selected. All the onions were examined for traces of rot or the formation of fungus sclerotia on the exterior. Only one variety of tomato, Livingstone Globe, was used.

For the culture of fungi or bacteria, Richard's nutrient solution, or the same solution modified by the addition of two grams of "Difco" peptone per litre of the solution. The latter solution proved to be better than the former for the growth of fungi and bacteria, and also it was better buffered. The former solution was better for the study of the effects of plant extracts on fungus and bacterial growth, because the solution was composed of substances of known composition.

The solid media used included "Difco" potato-dextrose agar, and nutrient gelatine. The former was used largely for culture work with various phytopathogens, but the latter was used mainly as a means of identifying certain Penicillia.

EXPERIMENTS AND RESULTS

Results of the Survey of Some Vegetable and Fruit Rots:—

During the survey special attention was given to rots of cabbage, celery potato, carrot, parsnip, onion, apple, and tomato. The rots of the last three plants were selected for a detailed study. The external appearance of each diseased specimen was noted, the object being to discover the nature of the rot, if it was soft or hard, and accompanied by the formation of sclerotia, spores, and odour.

After the external examination was complete, the organisms found in the rot were isolated by removing small portions of the decaying tissue and growing it on potato-dextrose agar; or where it was found that (Schizomycetes) were present, by the dilution method. It was often necessary to wash, but always sterilize the surface of the specimens. Corrosive sublimate, 1-500, was used for the sterilization; and sterile or distilled water for washing. Often the outside dry portions of some specimens had to be removed before washing could be finished.

In many soft-rotted vegetables, especially those emitting an offensive odour, numerous nematodes could be found. These were thought to aid the spread of saprophytes through the tissues of the rotted portion of the specimen.

In Table I the fungi or other organisms are listed in groups according to the host on which they were found. In most cases only one parasite was found associated with several saprophytes, while in fewer instances two parasites were associated. Three pathogens were never found in the same lesion.

In the apple, when *Penicillium expansum* was reponsible for the rot, no other genus of micro-organisms was found present. In some specimens rotted by the "Pink Rot" fungus, *Cephalothecium roseum*, it was a rot following injury by the Scab fungus *Venturia inaequalis*. The Brown rot fungus, *Sclerotinia fructicola*, was found on a few specimens, the limitation of the numbers being probably due to the low temperature of the store-rooms. In such cases, a secondary infection, caused by *Penicillium expansum*, usually occurred.

In the cabbage the dominant rot was caused by *Sclerotinia perplexa*, the Botrytis stage being most in evidence. In a few specimens the rot was rendered watery due to the invasion of saprophytic bacteria and yeasts. An abundant growth of *Phycomyces sp.* was often observed, but this fungus existed solely as a saprophyte.

In the carrot the predominating rot was caused by *Sclerotinia sclerotiorum*. Some of the rotted tissues were also invaded by *Erwinia caratovora*, but the low temperature of the store-rooms inhibited the growth of this pathogen considerably. Saprophytic micro-organisms, unidentified, were also present.

In the potato the typical rot was caused by *Fusarium sp.*, probably species *oxysporum*. In one or more cases *Verticillium albo-atrum* was found in the lesions A considerable amount of rot was caused by the late blight fungus, *Phytophothora infestans.*

In the onion, *Botrytis allii* was the predominating pathogen. *Botrytis byssoidea* and *Botrytis squamosa* were also found on some of the decayed specimens, the latter fungus chiefly on the white-skinned onions. *Botrytis allii* was responsible for at least seventy-five percent of the diseased bulbs. Yeasts and bacteria were also present, and sometimes *Pythium debaryanum* was found as a saprophyte.

In the parsnip *Sclerotinia sclerotiorum* caused a soft rot of the cortex of the root. Some saprophytic yeasts were also found in the lesions.

In the tomato the dominant rot was caused by *Botrytis sp;* and it either caused the rot independantly or following the attacks of the Leaf Mold fungus, *Cladosporium fulvum.*

From the above survey the writer decided that there were at least three types of associations: (1) where associated organisms are seldom found, as in rots caused by *Penicillium expansum*, (2) where pathogens can mix freely, as in the carrot, where *Sclerotinia sclerotiorum* and *Erwinia caratovora* were found in the same lesion, and, (3) where the parasite is usually followed by a saprophyte.

TABLE I.—The organisms found in some vegetable and fruit rots.

Host	Parasites	Saprophytes
Apple	*Sclerotinia fructicola* *Penicillium expansum.* *Cephalothecium roseum.*	None.
Beet	*Phoma betæ*	*Schizosaccharomyces sp.*
Cabbage	*Sclerotinia perplexa*	*Phycomyces sp.* *Schizosaccharomyces sp.* Bacteria.
Carrot	*Sclerotinia sclerotiorum* *Erwinia caratovora.*	*Schizosaccharomyces sp.*
Celery	*Sclerotinia sclerotiorum* *Erwinia caratovora.*	None.
Onion	*Botrytis allii* *Botrytis byssoidea* *Botrytis squamosa*	*Pythium debaryanum (?)* *Schizosaccharomyces sp.* *Bacteria.*
Parsnip	*Sclerotinia sclerotiorum*	*Schizosaccharomyces sp.*
Potato	*Fusarium oxysporum (?)* *Verticillium albo-atrum.*	*Rhizopus nigricans.*
Tomato	*Botryiis sp.* *Cladosporium fulvum.*	None.

Association of Phytopathogens in Culture:—

The following fungi were chosen for the study of association of phytopathogens in culture: *Penicillium expansum, Sclerotinia fructicola, Botrytis sp.* (tomato), *Cladosporium fulvum, Sclerotinia sclerotiorum, Botrytis allii,* and a slow growing ,undetermined fungus isolated from decaying carrots. The inoculations were so made that each was grown in pure culture, or was paired with each other fungus of the group. All the cultures were grown in (duplicate) on Richard's modified nutrient solution. The main object of this experiment was to determine the effect of the association on growth, sporulation, mycelial and sclerotial development, acid production, and dominance in culture. The cultures were incubated at 20-24°C. for ten days, observations being made daily. At the end of the experiment the H-ion concentration of each culture medium in the flasks was determined, in order that the amount of change could be observed. The data obtained from the above experiment are given in Table II.

The results from this experiment show that there is a tendency for some species of fungi to inhibit the growth of associated fungi. The H-ion concentration of the medium is a fair indication of the amount of dominance, for when almost complete dominance of one of the associated fungi was observed, the H-ion concentration of the medium was similar to that of the medium on which a pure culture of the dominant organism was growing. In a few cases the fungi grew equally well in mixed culture as in pure culture. Sometimes a definite stimulus was given to the growth of the associated fungi on account of the association.

In a similar experiment the organisms isolated from carrot rots were grown together in Richard's modified solution. Though the organisms occurred on the same host, yet there was a tendency for some of them to suppress the growth of others associated with them. The fungi in this case included three strains of *Sclerotinia sclerotiorum*, and the unidentified fungus used in the previous experiment. Also two schizomycetes, *Erwinia caratovora* and *Schizosaccharomyces sp.* were used in the mixed cultures.

In the latter experiment it was seen that there was a definite dominance of fungi over bacteria in mixed culture, although in such cultures the growth of the fungi was materially lessened. Fungi were still able ro grow well on the used culture medium after all growth of the yeast and bacteria had ceased.

Effect of Plant Extracts on Association:—

It has been known for a number of years that vitamines, or "essential food factors", are necessary for the proper physiological functioning of living matter. The chemical composition of those substances is not fully understood, but they appear to be classified according to their physiological functions. They are present in all living matter; and for a time in dried remains of such living matter, but they will not live on indefinitely.

The writer recently carried out a joint experiment with some soil bacteria with the objects of investigating the effects of plant extracts on the growth of some Nitrogen-fixing bacteria. Extracts from various plants were prepared by grinding up 20-gram portions of the plant tissue in 100 cc. of water, and then filtering the juice through a sterile, clean Berkefeld filter (size N). The bacteria were grown on sterile N-free Ashby's medium, to which various amounts of the extracts were added.

It was found that all extracts did not cause similar stimulation.

TABLE II.—The association of phytopathogens in mixed culture

Culture	Final pH	Sporulation	Mycelium	Sclerotia	Dominance
(1) *P. expansum*	3.3	++++	+++	0	
do	3.3	++++	+++	0	
(2) *S. fructicola*	4.8	+++	++++	0	
do	4.7	+++	++++	0	
(3) *Botrytis sp.*	3.6	++++	++++	++	
do	3.6	++++	++++	++	
(4) *C. fulvum*	5.7	+++++	+++	0	
do	5.7	+++++	+++	0	
(5) *S. sclerotiorum*	4.8	++	++++	++++	
do	4.9	++	++++	++++	
(6) *B. allii*	4.9	++++	++++	++	
do	4.9	++++	++++	++	
(7) Unknown fungus	5.9	0	++	0	
do	5.7	0	++	0	
(1) and (2)	3.1	++++	+++	0	(1) dominant
do	3.3	++++	+++	0	" "
(1) and (3)	3.3	++++	++++	++	equal
do	3.5	++++	+++	++	"
(1) and (4)	3.3	++++	+++	0	(1) dominant
do	3.3	++++	+++	0	" "
(1) and (5)	3.2	++++	+++	0	equal
do	3.1	++++	+++	0	"
(1) and (6)	3.3	+++	+++	0	(1) dominant
do	3.3	+++	+++	0	" "
(1) and (7)	3.2	++++	+++	0	" "
do	3.2	++++	+++	0	" "
(2) and (3)	4.8	+++	++++	++	(3) dominant
do	4.7	+++	++++	++	" "
(2) and (4)	4.9	++++	+++	0	equal
do	5.0	++++	+++	0	"
(2) and (5)	3.9	+++	++++	0	(5) dominant
do	3.6	+++	++++	0	" "
(2) and (6)	3.8	+	++++	0	(6) "
do	3.6	+	++++	0	" "
(2) and (7)	3.5	+++	++++	0	(2) "
do	3.3	+++	++++	0	" "
(3) and (4)	3.6	++++	+++++	0	(3) "
do	3.7	++++	+++++	0	" "

TABLE II.—The associatien of phytopathogens in mixed culture—*Continued.*

Culture	Final pH	Sporulation	Mycelium	Sclerotia	Dominance
(3) and (5)	3.8	+++	++++	++	(3) dominant
do	3.8	+++	++++	+++	" "
(3) and (6)	3.8	+++	++++	++	" "
do	3.8	+++	++++	++	" "
(3) and (7)	3.9	+++	++++	++	" "
do	3.8	+++	++++	++	" "
(4) and (5)	3.9	+	++++	++	(5) "
do	3.9	+	++++	++	" "
(4) and (6)	4.2	+	++	0	(6) "
do	3.9	++	+++	0	" "
(4) and (7)	5.4	++++	++++	0	(4) "
do	5.5	++++	++++	0	" "
(5) and (6)	3.9	+++	++++	++	equal
do	3.9	+++	++++	++	"
(5) and (7)	3.9	+++	+++++	+++	(5) dominant
do	3.9	+++	+++++	++++	" "
(6) and (7)	5.1	+	++++	0	(6) "
do	5.0	+	++++	0	" "

Numerous other workers have obtained contradictory results when working on the effect of growth promoting substances such as found in plant extracts. Some of these investigators have shown that such extracts have no beneficial effect on the growth of fungi, except perhaps in the earliest stages. In the case of bacteria stimulation of growth by plant extracts has been observed in nearly all cases, and along with increased growth there also was an increase in the physiological efficiency of the stimulated organism.

The writer performed an experiment to demonstrate the effect of some plant extracts on the development of some rot-producing fungi and bacteria. The extracts were prepared by expressing the cell sap from sound specimens of apples and onions, and passing the juice so obtained through a sterile Berkefeld filter as before. Autoclaving was avoided to prevent the precipitation of water-soluble proteins which are present in the juice.

The extracts were added to Richard's medium at the rate of one drop to one cubic centimeter per flask containing fifty cubic centimeters of the cool, sterile medium. Spore suspensions of the organisms were prepared beforehand, each suspension containing approximately ten thousand spores per cubic centimeter. One cubic centimeter was added to each flask as the inoculum.

The effect of apple extract on the growth of *Sclerotinia fructicola* and *Penicillium expansum* was studied. These two fungi were grown in pure culture or in association, and the effect of the extract was observed in each case. The cultures were incubated at 20-24°C. for ten days, and at the end of the period the mycelium was charted in diagrammatic form. These results are shown in Fig. I. Though daily observations were made, there appeared to be no stimulus.

TABLE III.—Effect of plant extracts on growth of N-fixing Bacteria

Extract	Amount of extract in drops	Amount of growth of	
		Azotobacter	Rhizobium
Decomposed Wheat straw Containing also Azotobacter	1	+	++
	1	+	++
	5	++	+++
	5	+	+++
	10	++	+++
	10	+++	++++
Green alfalfa	1	+	++
	1	+	++
	5	+++	++++
	5	+	++++
	10	+	++++
	10	+++	++++
Barley Meal	1	++	+++
	1	++	+++
	5	+++	++++
	5	+++	++++
	10	++	++++
	10	++++	++++
Ground Yeast Cells	1	++	++
	1	++	++
	5	+++	++++
	5	+++	++++
	10	++	++++
	10	++++	++++
Decomposed wheat Straw without Azotobacter	1	+	+
	1	++	+
	5	+	+++
	5	+	+++
	10	+	+++
	10	+	+++
No Extract	Tube 1	++	+
	" 2	+	+
	" 3	+	+
	" 4	+	+

TABLE IV.—The effect of onion extract on the growth of *Erwinia caratovora*

Amount of extract per 50 c. c. of medium	Bacterium in pure culture (1)			Bacterium plus fungus (2)		
	Plate 1	Plate 2	Average	Plate 1	Plate 2	Average
No extract	1376	1520	1448	1520	840	1180
One drop	2800	2480	2660	1574	912	1243
Two drops	4560	4738	4649	1728	1480	1604
Three drops	4640	4380	4510	2080	1840	1960
Four drops	4416	4190	4303	3520	3040	3280
Five drops	7280	6450	6855	5600	5428	5514
½ c. c	3360	3940	3650	2848	2752	2800
One c. c	4885	5286	5085	1448	1680	1564

(1) *Erwinia caratovora* growing together with *Botrytis allii.*
(2) *Erwinia caratovora* alone in pure culture.
Note:—The lesser numbers of bacteria in the cultures which include the fungus may be due to increased acidity of the medium beyond the point of tolerance of the bacterium to the acid.

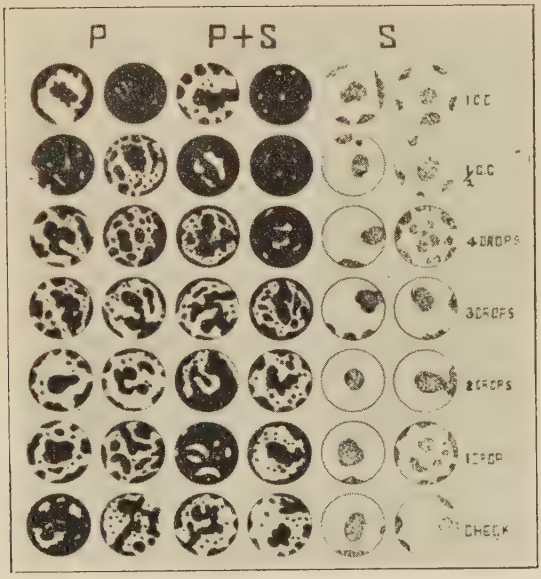

Figure 1.—Showing the effect of the addition of apple extract on the growth of *Penicillium expansum* (P), and *Sclerotinia fructicola* (S) in pure cultures or in combination (P.-S). No increased growth of either organism was observed.

A similar experiment was carried out with two organisms found associated in onion rots. One of these was a fungus, *Botrytis allii*, and the other a bacterium, *Erwinia caratovora*. The purpose of this experiment was to determine the effect of onion extract on the growth of the above organisms.

The spore suspension in the case of the fungus was prepared as above, but in the case of the schizomycete a suspension which equalled approximately in turbidity that of the fungus spore suspension was found by preliminary experiment to contain about ten to fifteen times as many organisms per cubic centimeter. Therefore the bacterial suspension was diluted accordingly.

Inoculations were made as in the experiment with the apple-rotting fungi, and the same cultural conditions were used. However, it was found to be impractical to leave the bacterial cultures for the full ten days as was done with the fungus cultures, as all the bacterial cultures tended to become equal in turbidity after three or four days. Therefore final data on the bacterial cultures were taken after the third day.

In making the estimate of the amount of growth in the flasks, it was found that there did not appear to be enough difference in the fungus cultures to warrant the conclusion that onion extract, as prepared above, had any influence on the growth of *Botrytis allii*. However, there was an obvious increase in growth of the numbers in the bacterial cultures. The relative concentration of the bacteria was measured by diluting one drop of the bacterial suspension with 100 c.c. of water (sterile), and then plating out 1 c.c. of this dilute suspension with melted potato-dextrose agar. The colony counts were an index of the effect of different amounts of the onion extract on the growth of the organism. Results are shown in Table IV.

It was noted that while the onion extract stimulated all the cultures of *Erwinia caratovora*, whether in pure culture or in association with *Botrytis allii*, the growth was greater in the pure cultures than in the mixed. Apparently only small amounts of the extract were necessary to bring about a definite stimulus.

The Influence of Temperature on Growth and Association of Some Phytopathogens in Artificial Media.

An attempt has been made to determine the influence of temperature on the development and association of some rot-producing organisms. It has been observed during the survey of rots in storage that apples kept at a low temperature were more likely to be rotted by *Penicillium expansum* than by any other fungus, while *Sclerotinia fructicola* rotted apples more readily when they were kept at temperatures above 15°C. Apples at room temperature were about equally susceptible to the attacks of both organisms, but the rot caused by *S. fructicola* progressed much faster than the other. With this observation as a begining, the writer commenced a series of investigations of the temperature relationships of fungi causing onion, tomato, and apple rots.

In the studies of the effects of temperature on the above relationships, three

distinct, and widely separated temperature ranges were used; one, a relatively high temperature, 30-34°C.; the second, room temperature, 20-24°C.; and a third, store-room temperature, 4-8°C. Six different fungi were used and were grown in pairs as follows: *Botrytis allii* and *Botrytis byssoidea, Botrytis sp.* and *Cladosporium fulvum, Penicillium expansum* and *Sclerotinia fructicola.* Each pair caused a rot of a different plant, the onion, tomato, and apple respectively. In each case the fungi were grown either on potato-dextrose agar in Petri plates, or in small Erlenmeyer flasks of 150cc. capacity, each containing 50cc. of Richard's modified nutrient solution. The inoculum was added in the form of spores when they could be obtained in sufficient quantities, or as mycelium. Approximately 10,000 spores were used in the inoculation of each flask. Cultures were incubated at the three temperatures for 10 days.

In the apple-rotting fungi, *Sclerotinia fructicola* was found to grow best at 30-34°C. or 20-24°C., slightly better in the latter, but very slowly at the lowest temperature. At the highest temperature the mycelium was closely appressed to the surface of the medium. Sporulation was moderate at this temperature, but the spores were found to be unable to survive for more that four days after formation. No zonation was observed in the colonies growing on agar. At room temperature sporulation was abundant, spores were viable for a long time, and zonation was quite distinct. At 4-8°C. growth was very slow, for germination is retarded. Practically no spores are produced at this temperature.

Penicillium expansum grew best at 20-24°C. Sporulation and zonation was abundant and distinct. At 30-34°C. growth was very slow, sporulation less marked, no zonation, and a reddish-brown pigment was diffused from the colony into the medium. No pigment was formed at the other temperatures used. At 4-8°C. germination of spores was noticeably retarded, but afterwards the growth was more rapid than at 30-34°C.

In mixed cultures there was a distinct retardation in growth of each fungus as the colonies approached each other on the solid medium in Petri plates, no matter at what temperature they happened to be growing. Otherwise, sporulation, growth, and zonation were exactly as in the pure cultures. The relative amounts of growth varied with the temperature, for at 30-34°C. *Sclerotinia fructicola* occupied most of the surface of the medium; at 20-24°C. the growth of both fungi was rapid but nearly equal; and at 4-8°C. growth was also nearly equal but retarded.

Similar results were obtained in the cultural studies of the onion-rotting fungi, *Botrytis allii* and *Botrytis byssoidea.*

Botrytis allii grew well at 30-34°C. or at 20-24°C., but growth at the higher temperature was less. Similarly, growth was very much reduced at 4-8°C. Sporulation was abundant at both the higher temperatures, but very much reduced at the lowest temperature. In all cases the mycelial growth was appressed to the medium, not flocculent and raised as with *Botrytis byssoidea.*

This latter organism grew best at 20-24°C. and considerably less at the two extremes of temperature. Growth was about equal in these cases, but in

both instances the extent of the mycelium was greater than that of *B. allii*. Spore production was slight at all temperatures, but it was best at 30-34°C. At this latter temperature the mycelium was comparatively compact, not loose and flocculent as at the other temperatures. Germination in cold storage occurred at least one day before that of *B. allii*.

In mixed cultures the growth of both fungi was approximately similar to that obtained in the pure cultures of each fungus. There was no overgrowing of one fungus by the other, and the total area occuppied by each fungus depended directly on the temperature.

In the tomato-rotting fungi, *Botrytis sp.* and *Cladosporium fulvum* they differed considerably in amount of growth, for in all cases the former grew faster than the latter. There was a difference, however, in the relative rate of growth and sporulation of both fungi when grown at varying temperatures, whether in pure culture or in association.

At 30-34°C. growth was abundant in both cases, but the Botrytis grew much faster than the Cladosporium, and so covered practically all of the medium surface. Abundant spore production was obtained with both fungi, though the Botrytis produced relatively few spores when compared to the spore numbers in Cladosporium. The latter fungus grew as well at this temperature as at 20-24°C. In the former, the growth was slightly less than at room temperature, but sporulation was greater. The mycelium showed a tendency to produce small sclerotia much more rapidly than at room temperature. A slight tendency towards the production of Saltants was observed, the variation consisting of the formation of sectors of dark mycelium.

At 20-24°C. growth of *Botrytis sp.* was greater than at the higher temperature. More aerial mycelium was formed, but comparatively few spores. There was no pigment production by the mycelium. The growth of *Cladosporium fulvum* was slightly greater than at the higher temperature.

At 4-8°C. Growth of *Botrytis sp.* was comparatively slow. The mycelium was closely appressed to the medium. No spore or pigment production was observed. *Cladosporium fulvum* was retarded considerably in germination, so that the colonies did not become visible until after four days had elapsed from the time of inoculation.

Association of phytopathogens at varying temperatures was best illustrated when the above pathogens were cultured on liquid media. Richard's modified nutrient solution was used, distributed as in the other experiments, and the same number of spores used for inoculation in each, where sufficient quantities of spores were formed. The flasks so prepared were divided into three series, each series being placed at a different temperature and consisting of a duplicate set of cultures.

At 30-34°C. *Penicillium expansum* grew poorly ,but the other organism associated with it grew well. Sporulation was less in each case than at room temperature. In mixed cultures it was found that where there was a tendency, at 20-24°C., for the Pencillium to suppress the Sclerotinia, when the spore num-

bers were equal, here the latter fungus could grow well at a higher spore concentration of the former fungus than was possible at room temperature. It was plainly a case where the high temperature had decreased the physiological activities of the inhibiting organism, and thus the other could grow much better, since it suffered less inhibition.

At 20-24°C. both *Penicillium expansum* and *Sclerotinia fructicola* grew well. Sporulation of the latter fungus was considerably less than that obtained from cultures on potato-dextrose agar. In mixed cultures there was a tendency for the former organism to suppress the other, unless the spore numbers of the latter organism were considerably in excess of the former. The effect of the temperature on the growth of the above fungi can be seen in Figure II, (a, b, c)

In the case of the onion-rotting fungi, *Botrytis allii* and *Botrytis byssoidea*, suppression of either organism did not occur, no matter what the spore concentration happened to be.

At 30-34°C. growth was abundant in both fungi. *Botrytis allii* predominated in the mixed cultures, but the other was not suppressed. The predominance of the former organism appeared to be due chiefly to the temperature, a similar phenomenon to that observed when the two fungi were grown on potato—dextrose agar. There was less growth of each organism in the mixed culture than in the pure cultures, but the total appeared to be about the same in both cases.

At 20-24°C. growth of both organisms was good. Sporulation was abundant in the case of *Botrytis allii*, but slight in *Botrytis byssoidea*. Some sclerotia were formed on the surface of the medium by the latter fungus. In association both fungi grew well. There was no inhibition of growth, though neither organism grew as well as in pure culture.

At 4-8°C. growth was very much reduced in both fungi, either in pure or in mixed cultures. In the mixed cultures, however, *Botrytis byssoidea* predominated in all the flasks.

In the case of tomato-rotting fungi, *Botrytis sp.* and *Cladosporium fulvum*, it was found that the former organism grew well at low temperatures, while the latter organism grew well at high temperatures. The results for each temperature used are as given below.

At 30-34°C. the growth of both organisms was somewhat reduced from that obtained at 20-24°C. *Botrytis sp* .appeared to be more inhibited at this temperature than *Cladosporium fulvum*, which sporulated freely and grew well. The former organism did not sporulate freely, but more so than at either of the lower temperatures. In association, the former fungus was sompletely suppressed where the spore concentration of the latter was high, and this suppression was more complete that at 20-24°C. The cultures at this temperature are shown in Figure III (a).

At 20-24°C. both fungi grew well, many spores were produced. *Cladosporium fulvum* grew well, and the spore production in its case exceeded that of the Botrytis many times. Suppression of the latter organism occurred only when the spore number in the inoculum of the former organism was the highest.

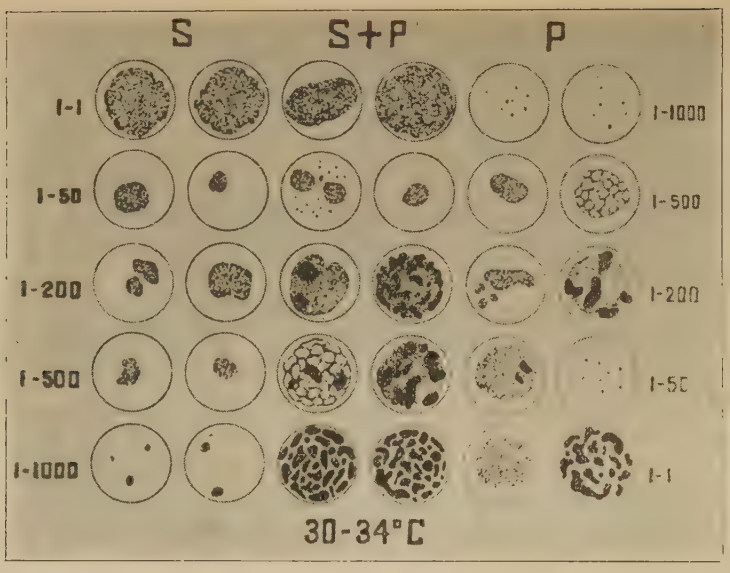

FIGURE II.—(a). Growth of *Penicillium expansum* (P), and *Sclerotinia fructicola* (S) in pure cultures and in association at 30-34 C. Heavy shading shows colonies of *P. expansum*, light shading those of *S. fructicola*, except when *P. expansum* is also present, where it shows submerged colonies of the latter fungus.

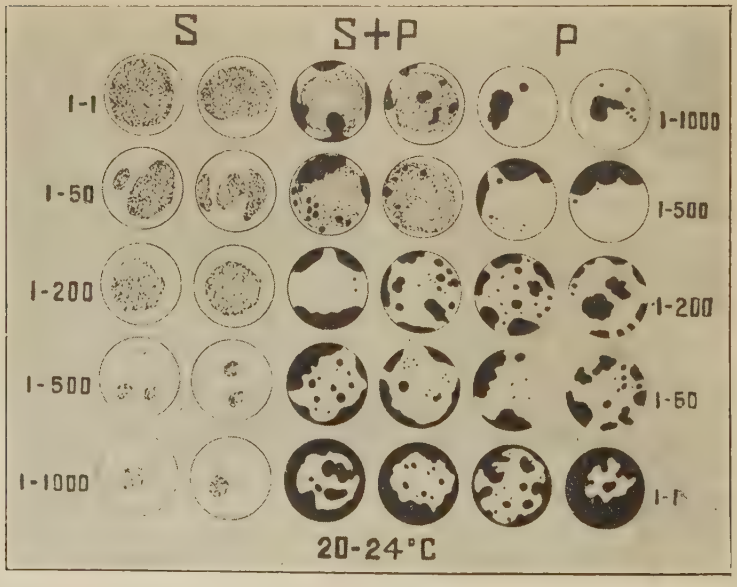

FIGURE II.—(b). Growth of *Penicillium expansum* (P), and *Sclerotinia fructicola* (S) in pure culture and in association, at 20-24 C. Heavy shading shows colonies of *P. expansum* while light shading shows colonies of *S. fructicola*. Figures at the sides indicate the spore concentration of each fungus.

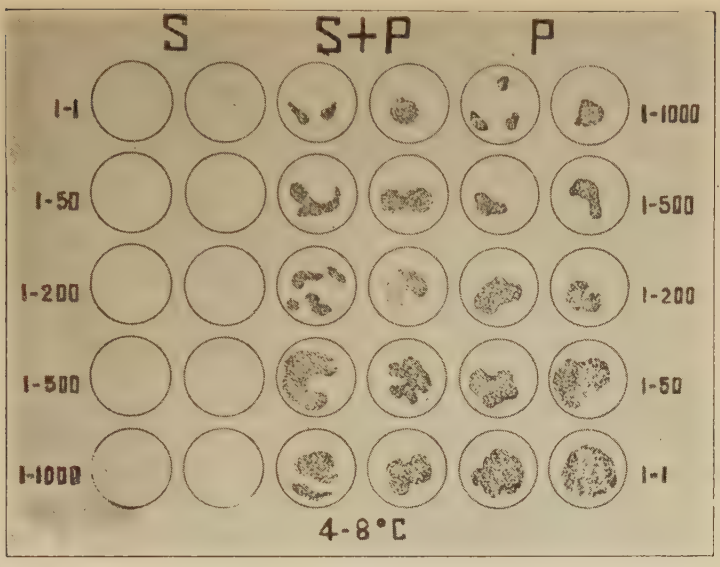

FIGURE II.—(c) Growth of *Penicillium expansum* (P), and *Sclerotinia fructicola* (S) in pure culture and in association at 4-8° C. Shading shows colonies of *P expansum*. No growth of *S fructicola* occurred. Figures on sides indicate spore concentration of each fungus.

At 4-8°C. *Botrytis sp.* grew well, but no spores were produced. *Cladosporium fulvum* did not form much mycelium, due to the low temperature. In mixed cultures the former organism predominated, but the latter fungus appeared only in the cultures containing the maximum number of its spores. The cultures are shown in graphic form in Figure III (c).

The effect of the different temperatures on the growth and association are shown in chart form in Figure III (a, b, c).

From the above results the writer concluded that the temperature at which the above pathogenic fungi grew was a factor which partly determined the growth of each fungus at a definite temperature. As was found in later experiments, the temperature variations produced the same changes in the host as well as in artificial cultures, for the temperature at which the host plants were stored largely determined the nature of the rot.

The influence of the Amount of Inoculum on Association:—

During preliminary investigations on association between *Sclerotinia fructicola* and *Penicillium expansum*, it was observed that when equal numbers of spores of these fungi were used, there was a tendency for the latter fungus to be suppressed by the latter when in association in artificial culture. The writer, having in mind the possible influence of spore number on the presence or absence of a fungus in a rot, investigated the problem, and after dealing with several fungi, came to the conclusion that the amount of inoculum has a direct influence on the presence or absence of an organism in culture.

The cultures of the various fungi were grown in Richard's modified nutrient solution, adjusted to pH 6.5, and placed in 50c.c. lots in small Erlenmeyer flasks.

A heavy suspension of spores, when such could be obtained from culture. These spores were suspended in sterile tap-water and the supension diluted according to need. The standard suspension of spores as prepared contained about 10,000 spores per cubic centimeter. Dilutions from this standard suspensions contained approximately 200, 50, 20, and 10 spores per cubic centimeter. All five spore concentrations were used in making the inoculations.

When inoculations were made, one cubic centimeter of one of the spore suspensions was used for each flask. In making these inoculations in the mixed cultures, the highest cencontration of spores of one organism was mixed with the lowest concentration of spores of the second, and in further inoculations gradually decreasing spore concentrations of the first fungus, but increasing spore concentrations of the second fungus were used, until finally the least concentrated suspension of the first was mixed with the most concentrated suspension of the second fungus.

When the inoculations were complete, the flasks were divided into three series to be placed at different temperatures. These temperatures were: 30-34°C.; 20-24°C.; and 4-8°C. The cultures were kept at these temperatures for ten days, when the amount of growth was charted. The results are shown in Figures II. and III.

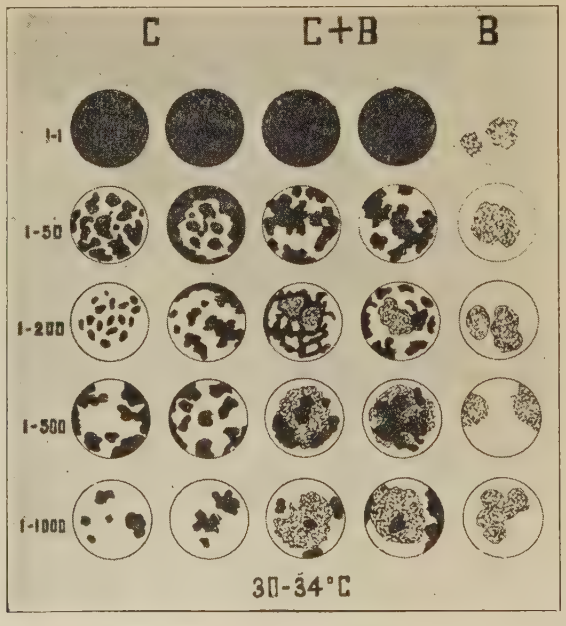

FIGURE III.—(a). Growth of *Botrytis ss.* and *Cladosporium fulvum* in pure culture and in association. Heavy Shading represents growth of *Cladosporium fulvum* (C), light shading that of *Botrytis sp.* (B). The figures on the side indicate the spore concentration of the former organism only, for the same amount of inoculum of the other organism was used in each case.

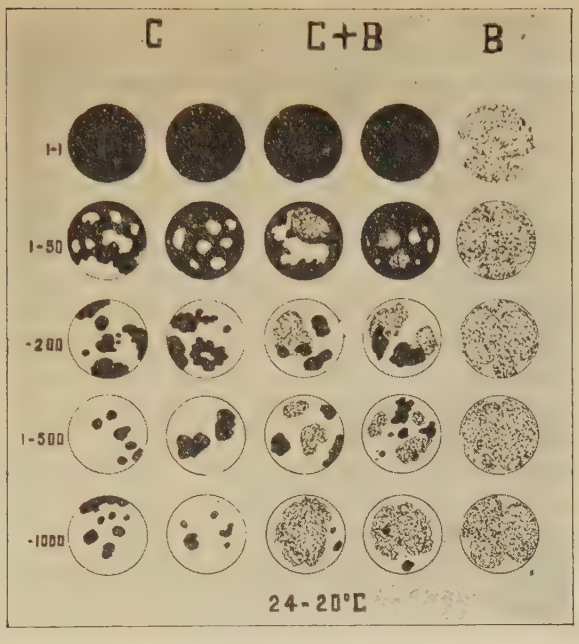

FIGURE III.—(b). Growth of *Botrytis sp.* (B) and *Cladosporium fulvum* (C) in pure cultures and in association at 20-24°C. Heavy shading represents growth of *C. fulvum*, light shading that of *Botrytis sp.* The figures at the side indicate the spore concentration of the former organism only, as the same quantity of inoculum of the latter was used in each case.

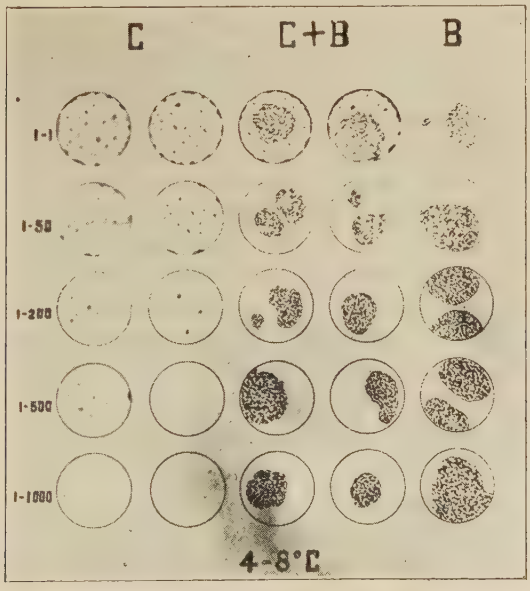

FIGURE III.—(c). Growth of *Botrytis sp* (B) and *Cladosporium fulvum* (C) in pure culture and in association, at 4-8°C. Heavy shading indicates growth of *C fulvum*, light shading that of *Botrytis sp* The figures at the side indicate the spore concentration of the former organism, as the same quantity of inoculum of the latter was used in each case..

In the case of apple-rotting fungi, *Penicillium expansum* and *Sclerotinia fructicola*, at 30-34°C. abundant growth was found in all cultures, except when the spore concentration in some pure cultures. Evidently the high temperature did not allow the fungi to form large colonies. In all the other cultures the surface of the medium was largely occupied by the colonies, which though small, were numerous. In the apple-rotting fungi *P. expansum* and S. *fructicola* sporulation was noticeably lessned in the latter, and was slightly reduced in the former. It was found that at this temperature the latter fungus was suppressed by the former unless the spore concentration was greater than 1-500 or 20 spores per cubic centimeter of the inoculum in the case of the latter organism.

At 20-24°C. growth was better in all cultures than above. Growth and sporulation was best where the fungi were grown in pure culture. The colonies were larger than above. However, in the mixed cultures of the above fungi, complete suppression of *S. fructicola* occured unless the spore concentration exceeded 1-200 or 50 spores per cubic centimeter. Where the spore concentration was above the limit mentioned, abundant growth occurred, but it was found that *Penicillium expansum* was also able to grow well in these cultures, even though the Sclerotina dominated. The results are shown in diagrammatic form in Figure II, (b).

At 4-8°C. *S, fructicola* did not grow well, even after the ten-day period of growth used in these experiments, so that the effect of spore concentration could not be judged as it could be at the higher temperatures. However, in the mixed cultures, after the above period had elapsed, it was seen that *P. expansum* had caused almost complete suppression of the other fungus at all spore concentrations. The results are shown in Figure II, (c).

In order to determine more accurately the effect of spore concentration on the growth of the above apple-rotting fungi, a more elaborate experiment was prepared. The apparatus used was similar to that above, but the gradation in spore concentrations was more gradual. The range of spore numbers varied from 10,000 to 10, in the following series: 10,000; 1,000; 500; 250; 125; 62; 33; 20; and 10. In the mixed cultures the combinations of the two organisms were made as above, but the temperature used was 20-24°C. The cultures were grown at this temperature for ten days, after which the growth of the fungi was charted as shown in Figure IV.

The results were almost similar to the results shown in Figure II, (b). Where the spores of *P. expansum* exceeded the number of spores of *S. fructicola* complete suppression of the latter fungus occurred. Where the number of the spores of the latter organism was greater than the former, then it was able to grow in the mixed cultures, but the Penicillium appeared likewise and grew almost as well as in pure culture.

In the onion rotting fungi, *Botrytis allii* and *B. byssoidea*, it was impossible to obtain spores in sufficient quantities to be used for inoculation purposes in an experiment similar to the above. However, in all experiments it was noticed that both fungi exhibited a distinct tolerance for each other in mixed culture,

even though sometimes the inoculum of one exceeded that of the other. There was never any definite suppression of either organism in the mixed culture, unless the temperature was distinctly unfavourable to the growth of one of them.

With the tomato-rotting fungi, *Cladosporium fulvum* and *Botrytis sp.* somewhat similar results were obtained as in the case of the apple-rotting fungi. An abundance of spores was produced by the former organism, so no difficulty was encountered in making the spore suspensions. In the latter organism the number of spores was considerably less, so instead of using spores, equal amounts of fungus mycelium were used. Spore concentration was varied in *C. fulvum* alone. Three series of similar cultures were prepared and placed at the same three ranges of temperature as were the apple-rotting fungi. After ten days the cultures were examined, and the amounts of growth charted and the growth of the colonies observed. The results were charted as shown in Figure III.

At 30-34°C. both fungi grew well, but sporulation was reduced in *Cladosporium fulvum*, while *Botrytis sp.* produced more spores than at the lower temperatures. As shown in Figure III, (a), the growth of the latter organism was suppressed completely in mixed cultures where the two highest spore concentrations of Cladosporium were used. In the other mixed cultures both organisms grew well.

At 20-24°C. abundant growth of both fungi was found in pure culture. Both grew better than at the higher temperature, though spore production was greater in Cladosporium but less in Botrytis. In mixed cultures only the highest concentration of Cladosporium spores was able to suppress the growth of Botrytis. The growth of the latter fungus was somewhat greater in proportion as the spore concentration of the associated organism was decreased. Therefore at room temperature, 20-24°C. the growth of *Botrytis sp.* appeared to be favoured more than at the higher temperature, and hence it was better able to overcome the inhibition due to the greater amount of the inoculum of the other fungus.

At 4-8°C. the growth of *Botrytis sp.* was very much in excess of that of Cladosporium, which hardly grew at all. Botrytis suffered no inhibition whatever, and it was able to suppress the growth of Cladosporium at all but the highest spore concentration of the Cladosporium.

Therefore, from the above experiments it has been concluded that not only the temperature but also the amount of inoculum determine the presence or absence of an organism in a mixed culture. All fungi do not possess the power to grow at similar ranges of temperatures, for one will grow at a temperature which is inhibitive to the growth of another. A fungus which may be completely suppressed at a certain temperature may be able to appear if the temperature is suitable to its growth, but not to the fungus which suppresses its growth.

Similarly, the amount of inoculum has been shown to influence the appearance of a fungus in a mixed culture. It has been shown that in a case where one fungus is strongly inhibited by another fungus as is *Sclerotinia fructicola* by

Penicillium expansum, the former organism is suppressed completely when the spore number of the latter exceeds the number of the former, or where the spore

FIGURE IV.—The effect of spore concentration of *Penicillium expansum* (P) and *Sclerotinia fructicola* (S) on growth and association. The figures at the sides indicate the dilution of the original suspension, which contained 10,000 spores per c. c.

numbers are equal. At all other spore concentrations the Sclerotinia is able to grow well for a time but is eventually slowed down in its growth by the action of Penicillium. In the tomato-rotting fungi, *Botrytis sp.* and *Cladosporium fulvum*, the latter also exhibits a tendency to suppress the former, but can do so only when the amount of inoculum appears to be very much in exceess of that of the associated organism. In the case of the onion-rotting fungi, neither appears to be able to inhibit the growth of the other, although more conclusive results can be obtained only by more definite experiments.

The Effect of Hydrogen-ion Concentration on Germination and Growth.—

A survey of the literature on this subject has revealed that a considerable amount of work has been done by previous workers on the relation between the H-ion concentration and spore-germination, fungus growth, and plant metabolism. The results of these workers on the relations specified above have agreed in some respects but differed in others, and this difference can be traced to the fact that there was little uniformity in the methods, media, and organisms employed by them.

The writer confined his attention to the six fungi studied above, the particular phases of study being, (1) the effect of the H-ion concentration on spore germination, (2) the effect on growth and association, (3) the study of the "isometabolic point" of several rot-producing fungi, and (4) the effect of changing the used media by autoclaving, neutralizing, etc.

In the study of spore germination, the spores were suspended in the medium which was tested and germinated by the hanging drop method. In some cases distilled water was used, or in others the staled medium on which the fungi had been growing, or the unused medium. The media in all cases were sterilized, and adjusted to a definite pH value. The hanging drops were examined under the microscope at eight hour intervals, being incubated at room temperature.

In the case of fungi which did not produce many spores, such as *Botrytis byssoidea*, small amounts of mycelium was used as the inoculum. The new growth from this mycelium could be easily observed by the radiating strands. Where the spores were used, the percentage germination was determined by taking the average of five fields under the high power objective of a microscope. Where spores were not used, the amount of growth was defined by the use of a symbol, as follows: slight growth (+), fair growth (++), medium growth (+++), good growth (++++), very good growth (+++++), no growth (0).

In the first experiment the influence of H-ion concentration on the germination of the spores of *P. expansum* and *S. fructicola* was studied. Two media were used, one being sterile distilled water while the other being Richard's modified nutrient medium, both adjusted to various pH values ranging from pH 1.5 to pH 6.5. The results are shown in Table V.

From the date shown in this table it is seen that there was a lesser percentage of spore germination in the distilled water than in the Richard's solution.

There was a distinct effect of acidity on the germination in the hanging drops, for the count of the germinated spores revealed the fact that acidity not only can decrease the amount of germination, but can also retard it. *P. expansum* was better able to germinate in very acid media than *S. fructicola*. Germination was best at pH 4.2-5.3 in the former, but slightly higher in the latter.

A similar experiment was performed using the two fungi, *Botrytis allii* and *B. byssoidea*. The latter fungus did not produce enough spores which could be used in making an adequate suspension to be used in making the inoculations, so small portions of the mycelium had to be used instead. Therefore in the latter fungus the amount of growth is indicated by the use of the above mentioned symbols. Sterile tap-water only was used here. The results as shown in Table VI agree very well with those obtained in the previous experiment. Spore germination was possible at high acidity, but the growth at this pH value was less than in more alkaline media.

The germination of fungus spores in staled culture media was also studied. The purpose here was to determine if there were any substances, other than acids, present in the media which could lessen the percentage of spore germination through their action.

TABLE V.—The effect of H-ion concentration on spore germination of some apple-rotting fungi.

Initial pH of medium	Percentage of spore germination at eight-hour intervals							
	8 hrs.		16 hrs.		24 hrs.		32 hrs.	
	Dist. water	Rich. med.	Dist. water	Rich. med.	Dist. water	Rich. med.	Dist. water	Rich. med.
Penicillium expansum								
1.5	0	0	0	0	0	0	0	0
2.0	0	0	0	0	16	3	27	10
2.5	8	0	27	0	29	8	33	15
3.3	0	30	0	38	6	43	17	47
4.2	0	42	0	52	16	56	25	58
4.9	0	25	0	49	0	59	8	61
5.3	0	34	9	63	28	69	33	73
5.9	0	28	0	50	0	63	17	65
6.5	0	24	0	42	0	48	38	55
Sclerotinia fructicola								
1.5	0	0	0	0	0	0	0	0
2.0	0	0	0	0	0	0	0	0
2.5	0	0	0	6	0	9	3	15
3.3	0	6	14	32	19	45	27	49
4.5	0	9	17	45	34	53	48	58
4.9	7	21	29	31	44	57	55	63
5.3	20	34	32	47	51	59	62	62
5.9	23	28	31	36	42	49	47	56
6.5	18	23	25	38	42	47	45	67

TABLE VI.—The effect of H-ion concentration on spore germination or growth of some onion-rotting fungi

Initial pH of medium	Percentage Germination of *B. allii* at 8-hour intervals				Amount of Growth of *B. byssoidea* at 8-hour intervals			
	8 hrs.	16 hrs.	24 hrs.	32 hrs.	8 hrs.	16 hrs.	24 hrs.	32 hrs.
1.5	0	0	0	0	0	0	0	0
2.0	0	0	18	23	0	0	+	+
2.5	14	27	48	63	0	+	++	+++
3.0	34	44	58	62	+	+++	++++	++++
3.5	33	41	49	53	++	+++	++++	++++
4.0	29	34	50	53	++	++++	++++	++++
4.5	47	58	61	67	++	++++	+++++	+++++
5.0	35	51	59	64	++	+++	++++	+++++
5.5	42	49	62	73	+	+++	++++	+++++
6.0	38	45	52	59	++	+++	+++++	+++++
6.5	35	47	58	67	++	+++	++++	++++
7.0	37	52	66	69	++	+++	++++	+++++

In a preliminary experiment spores from pure cultures of *Penicillium expansum*, *Sclerotinia fructicola*, *Botrytis sp.* and *Cladosporium fulbum* were germinated and grown on quantities of Richard's modified medium. The cultures were incubated for ten days at 20-24°C., so that a mycelial mat covered the medium in the flasks. The mycelial mats were then removed, the medium filtered through a sterile Berkefeld filter, and the H-ion concentrations of each medium determined by the colorimetric method.

Four series of small flasks of 150c.c. capacity, each flask containing 50c.c. of autoclaved medium (Richard's modified) were used. To each of the series was added one of the four used media, at the rate of 1c.c. per flask. The same four fungi were used for the inoculation of the media, and the cultures again incubated for the same period and same temperature as above. In adding the staled medium the medium following the growth of *Sclerotinia fructicola* was added to the medium on which *Penicillium expansum* was to be grown. Conversely, the used medium following the growth of Penicillium was added to the cultures of Sclerotinia. With the other two fungi the same method was followed. The acidity of each medium was determined before and after adding the staled medium, whose pH values were known, and again after the ten day culture period.

The results of the experiment, as shown in Figure VII. show that in every case the addition of the used medium caused a decrease in the amount of growth. There was a distinct change in the H-ion concentration, there being a noticeable increase in acidity. In all cases, except *Botrytis sp.* the change was considerable. It was also observed that in some cases that small additions of the used media to some cultures caused a considerable decrease in growth of the fungus in culture. It appears, then, that some other substance besides acid is able to limit the growth of some fungi, for the increase in acidity due to the

addition of the staled medium was only slight, but the inhibition of growth was considerable. It appears that this toxic agent is probably powerful, for the inhibition of growth could not have been due to either acidity or to the lack of food materials in the medium.

As small amounts of the used media appeared to have such a marked effect on the growth of some fungi, the writer decided to test the effect of the above stales media on spore germination in certain fungi. As the media following the growth of Penicillium and *Botrytis sp.* appeared to be most powerful in causing a reduction of growth of the other fungi in above experiment, they were used in the study of spore germination. The media following a ten-day growth of these fungi were used, after being filtered through clean, sterile Berkefeld filters. The media were then used to make hanging-drop cultures of various fungi. These cultures were kept under bell-jars for 32 hours at room temperature, and examined at 8-hour intervals. The results are shown in Table VIII.

It was noted from the above experiment that both staled media had an inhibitive effect on spore germination. The Penicillium-staled medium appeared to be more powerful, although spores of the same fungus were able to grow in it. It appears that the staled medium following the growth of either fungus used in the experiment was best suited for the germination of its spores, but in each the germination was less than in the unused medium.

To prove further that acidity is not the important factor which prevents or inhibits the germination of fungus spores, the writer performed the following experiment.

TABLE VII.—The effect of small amounts of used media on growth of some fungi.

Fungus	Med. used	pH of medium	pH of used med. *	pH after 10 days	Amount of growth
(1) *P. expansum*	Rich. med.	6.1 (*)	.....	3.1	+++++
(2) *S. fructicola*	"	6.1 (*)	.....	3.5	+++++
(3) *Botrytis sp.*	"	6.1 (*)	.....	3.7	+++++
(4) *C. fulvum*	"	6.2 (*)	.....	4.2	+++++
P. expansum	Rich. med. plus med. from (2).	6.0	3.5	3.05	++++
S. fructicola	Rich. med. plus med. from (1).	6.0	3.1	3.15	++
Botrytis sp.	Rich. med. plus med. from (4).	6.0	4.2	5.3	++++
C. fulvum	Rich. med. plus med. from (3).	6.1	3.7	3.1	++

(*) These figures are derived from H-ion determinations of media on which the four fungi have grown. Into the cultures designated with the symbol. (*) no staled medium had been added.

TABLE VIII.—The effect of staled media on germination of the spores of some fungi.

Fungus	Unused Rich. mod. medium				Botrytis-staled medium				Penicillium-staled medium			
	Time in hours											
	8	16	24	32	8	16	24	32	8	16	24	32
P. expansum	0	38	73	79	4	39	52	67	16	35	42	55
S. fructicola	85	88	95	95	18	22	34	42	0	0	0	0
Botrytis sp	76	84	91	93	48	61	87	90	0	0	18	21
C. fulvum	0	43	94	95	0	12	21	34	0	0	0	4

Note:—All the spore germination data are given in percentages.

Pure cultures of *Penicillium expansum* were grown on Richard's modified nutrient solution at 20-24°C. for ten days. The mycelial mats were then removed, and the used medium passed through sterile Berkefeld filters into sterile flasks. The used medium was then divided into three portions treated as follows. One part was left untreated; the second part autoclaved at 15 pounds for 15 minutes, while the last part was adjusted in acidity so that it was the same as the unused medium, which was pH 5.6.

After the used media were prepared they were distributed in 50c.c. lots into small, sterile, Erlenmeyer flasks. These media were then inoculated with spores of *P. expansum and Sclerotinia fructicola*, either in pure culture or in combination. The same amount of inoculum, approximately 10,000 spores, was added to each culture flask. The cultures were then kept at the above temperature for ten days, when the final H-ion determinations were made, and the extent of the mycellial colonies charted as shown in Figure V.

The chart shows that the above fungi grew well on unused Richard's medium, but not so well on the other media. *P. expansum* grew better than Sclerotinia in all the cultures, and when the two fungi were in association, the former totally suppressed the latter. Penicillium was about equal in growth on the staled, unchanged medium and where the H-ion concentration was adjusted to that of the unchanged medium. On the autoclaved medium less growth occurred than on any other type.

Sclerotinia fructicola grew moderately well on fresh Richard's modified medium, but only slightly on the others. Of these, the autoclaved medium appeared to be the most favourable to the growth of this fungus. while the unchanged, used medium was distinctly very unfavourable to its growth.

There was very little change in the H-ion concentration of the media used in this experiment, except where considerable fungus growth was obtained. In all the cultures the media became more acid, although in varying degrees.

In the check unused medium the pH value changed from 6.5 to 6.3. Penicillium changed it to pH 3.1. In the used but adjusted medium the check changed from 6.5 to 6.4. Penicillium changed it to 3.4 while Sclerotinia to 4.2. The used and autoclaved medium did not change, but *P. expansum* changed it from pH 3.0 to 2.4, while Sclerotinia caused no change. In the unchanged used medium there was no increase in acidity of the check, but *P. expansum* brought it from pH 3.2 to pH 2.6. No change with Sclerotinia.

The conclusion that can be drawn from the above experiment seems to be that acidity is not the determining factor in the inhibition of fungus growth, although it appears to play a distinct part when the culture media are too acid, as will be shown in later experiments. There appear to be one or more toxic agents which causes this inhibition of growth, and this agent can be partially removed by autoclaving. It is probable that several factors combine to bring about the observed decrease of growth in the staled media.

After the above preliminary experiments were completed, the writer attempted to discover the effect of H-ion concentration on the growth of some rot-producing fungi. These fungi were grown on Richard's modified medium of different, known H-ion concentrations, and were either grown in pure cultures or in pairs; the pairs attacking the same host in each case. These fungi were, *Sclerotinia fructicola* and *Penicillium expansum* from the apple, *Botrytis allii*

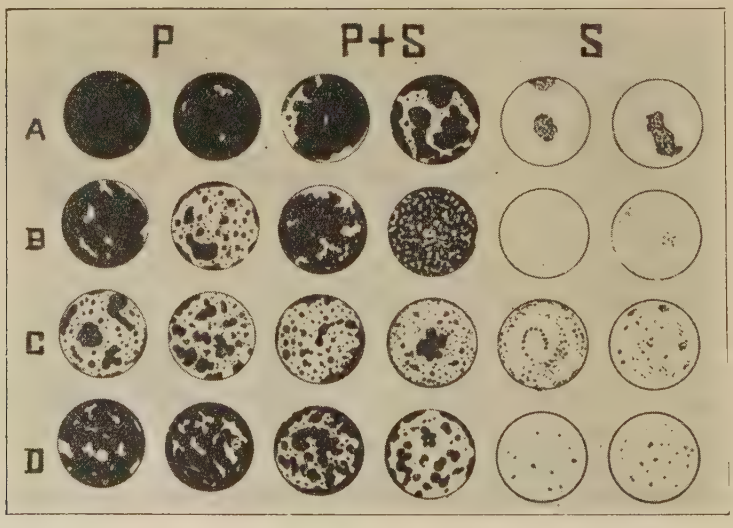

FIGURE V.—The effect of staled media on growth of *Penicillium expansum* (P) and *Sclerotinia fructicola* (S), grown in pure culture and in association. (A) the unchanged fresh Richard's modified nutrient medium. (B) The unchanged used medium (C) The autoclaved used medium. (D) The used medium. whose H-ion concentration has been adjusted to that of the fresh medium. Heavy shading shows the growth of Penicilium, light shading the growth of Sclerotinia.

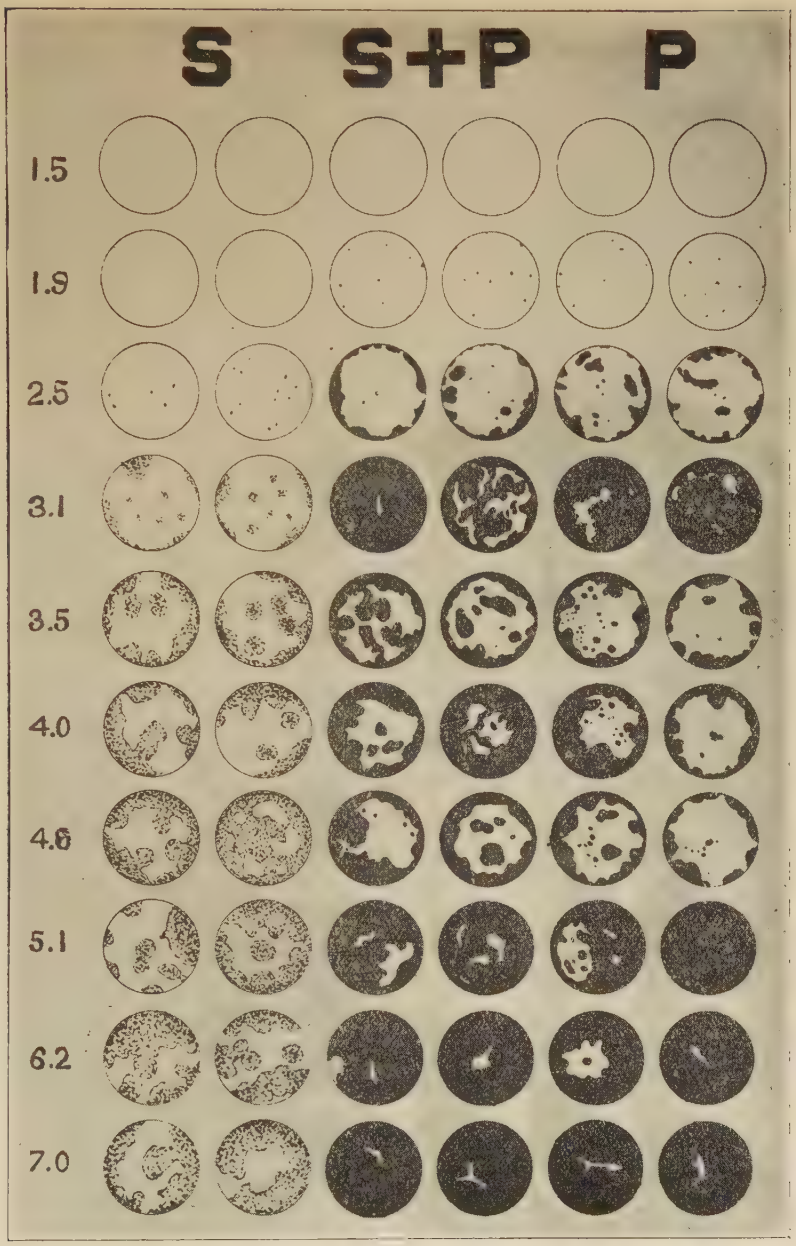

FIGURE VI.—The effect of H-ion concentration on the growth of *Penicillium expansum* (P) and *Sclerotinia fructicola* (S) inn pure culture and in association at 20-24°C. Heavy shading shows growth of *P expansum*, light shading that of *S fructicola*.

and *B. byssoidea* from the onion, and *Cladosporium fulvum* and *Botrytis sp.* from the tomato.

The fungi were grown singly or in pairs on Richards' modified medium at a pH of 1.5 to pH 7.0. About 10,000 spores were added to each flask where spores were available in sufficient quantities, er equal amounts of mycelium, where there were few spores. The cultures were all made in duplicate. Some uninoculated medium served to show any change in the pH values during the period of cultures, in the medium itself, other than the change produced by the fungi. After growth for ten days at room temperature the flasks were examined and the extent of the mycelia charted as shown in Figures VI, VII, and VIII.

When *P. expansum* and *S. fructicola* were grown in association, it was found that the former fungus was able to suppress completely all growth of the latter, no matter what the H-ion concentration proved to be. The former fungus grew at all pH values at and above pH 1.9, while the latter grew at pH 2.5 and above. There growth of both of the fungi was small when the medium was very acid.

It was noticed that the isometabolic point in the case of *P. expansum* was between pH 3.5 and pH 4.0. For *S. fruticola* this point was somewhat lower, about pH 2.0. These points are probably subject to a great deal of variation, for the figures obtained have not always been the same with consecutive experiments. The charts are shown in Figure VI.

With the onion fungi a similar experiment was performed. Here it was impossible to obtain sufficient spores of *Botrytis byssoidea* to be used for inoculating purposes, so mycelium was used. However, after ten days growth it was found, that *Botrytis byssoidea* grew in almost the same range of pH values as did *B. allii*, but was able to grow in a medium more acid than *B. allii* could tolerate. Both fungi preferred a slightly acid medium for their growth. Sporulation was abundant in cultures of *B. allii* at pH 5.0 and above. *B. byssoidea* did

TABLE IX.—Effect of H-ion concentration of growth of apple-rotting fungi

Initial pH	Check	*Penicillium expansum*		*P. expansum* and *S. fructicola*		*Sclerotinia fructicola*	
		Final pH	Growth	Final pH	Growth	Final pH	Growth
1.5	1.5	1.5	0	1.5	0	1.5	0
1.9	1.9	1.9	+	2.4	+	1.7	0
2.5	2.5	2.5	++	2.5	++	2.5	+
3.1	3.1	4.2	++++	3.0	++++	1.9	++
3.5	3.5	3.1	+++	3.1	+++	1.9	+++
3.9	3.8	3.8	+++	3.1	+++	1.9	+++
4.5	4.4	4.0	+++	3.9	+++	1.95	++++
5.0	4.8	4.1	++++	3.2	++++	3.15	++++
6.2	6.0	4.1	++++	3.5	++++	1.9	++++
7.0	6.7	3.9	++++	3.6	++++	4.0	++++

not form spores in noticeable quantities. Some sclerotial formation was observed in the latter fungus at pH 4.5 and above. When the two fungi were associated, both grew very well, and there appeared to be no tendency for one to suppress the other. The results are shown in Figure VII and Table X.

It was noticed that there was a tendency for the fungus to render the culture media more acid where the initial acidity was low, and less acid when the initial acidity was high. The amount of chagne was roughly correlated with the amount of growth. The uninoculated medium changed very slightly towards the acid side.

In the case of the tomato-rotting fungi, *Botrytis sp.* and *Cladosporium fulvum*, the procedure used in the above experiments was followed. Here also, as in *Botrytis byssoidea*, squares of mycelium of *Botrytis sp*, were used for inoculum. Cladosporium formed an abundance of spores, so that there was no difficulty in securing sufficient inoculum there.

It was observed in this experiment that Cladosporium grew very well in markedly acid media, more so than Botrytis, although the latter fungus was found able to tolerate more acid than the former. Sporulation was abundant in the cultures of *C. fulvum* at all H-ion concentrations allowing growth. There was a tendency for the fungus to form tufts of white, aerial mycelium in the acid media, pH 4.2 and below.

Botrytis sp. grew well at nearly all the H-ion concentrations used, though the amount of growth was approximately in inverse ratio to the degree of acidity. Sporulation was only slight, but formation of small sclerotia occurred in cultures of pH 5.2 and above.

In mixed cultures, *Botrytis sp.* was only suppressed at H-ion concentrations above pH 3.2 ,but it appeared in media which were more acid than this point. It appeared better able to resist the high acidity, and so was partly able to over-

TABLE X.—The effect of H-ion concentration on growth of onion-rotting fungi

Initial pH	Check	*Botrytis allii*		*B. allii* and *B. byssoidea*		*Botrytis byssoidea*	
		Final pH	Growth	Final pH	Growth	Final pH	Growth
1.5	1.5	1.5	0	1.5	0	1.5	0
2.0	2.0	2.0	0	2.0	+	2.0	+
2.4	2.4	2.5	+	2.5	++	2.4	++
2.9	2.9	2.6	++	2.7	++	2.7	++
3.4	3.4	2.6	++++	2.5	+++	2.5	+++
3.9	3.7	2.6	++++	2.4	++++	2.5	+++
4.5	4.2	2.4	++++	2.2	++++	2.7	+++
5.0	4.9	2.6	++++	2.2	++++	2.6	+++
5.5	5.3	3.2	++++	2.4	++++	2.4	++++
6.3	6.0	3.1	++++	3.1	++++	2.7	++++
7.0	6.8	3.1	+++	3.1	++++	2.7	+++

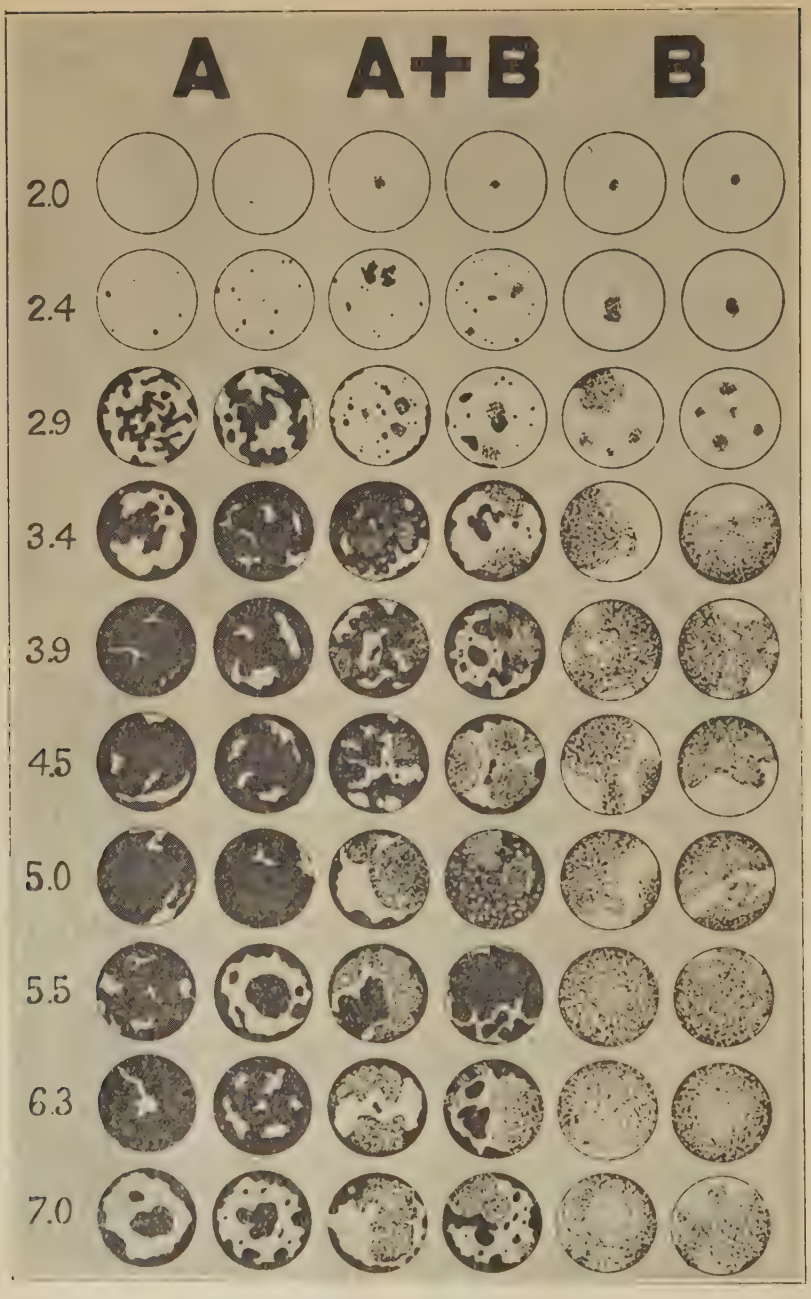

FIGURE VII.— The effect of H-ion concentration on the growth of *Botrytis allii* and *Botrytis byssoidea*, inpure cultures and in association. Heavy shading shows growth of *B allii* (A), light shading that of *B. byssoidea* (B). All cultures grown at 20-24oC.

TABLE X.—The effect of H-ion concentration on growth of onion-rotting fungi

Initial pH	Check	*Botrytis allii*		*B. allii* and *B. byssoidea*		*Botrytis byssoidea*	
		Final pH	Growth	Final pH	Growth	Final pH	Growth
1.5	1.5	1.5	0	1.5	0	1.5	0
2.0	2.0	2.0	0	2.0	+	2.0	+
2.4	2.4	2.5	+	2.5	++	2.4	+++
2.9	2.9	2.6	++	2.7	++	2.7	++
3.4	3.4	2.6	++++	2.5	+++	2.5	+++
3.9	3.7	2.6	++++	2.4	++++	2.5	+++
4.5	4.2	2.4	++++	2.2	++++	2.7	+++
4.9	4.9	2.6	++++	2.2	++++	2.6	+++
5.5	5.3	3.2	++++	2.4	++++	2.4	++++
6.3	6.0	3.1	++++	3.1	++++	2.7	++++
7.0	6.8	3.1	+++	3.1	++++	2.7	+++
4.9	4.9	2.6	++++	2.2	++++	2.6	+++
5.5	5.3	3.2	++++	2.4	++++	2.4	++++
6.3	6.0	3.1	++++	3.1	++++	2.7	++++
7.0	6.8	3.1	+++	3.1	++++	2.7	+++

come the inhibitory action of *C. fulvum*. The results of this experiment are shown in Figure XI and Table XI.

From the above experiments it was concluded that different fungi do not respond in the same way when grown at different degrees of acidity, but that there is a distinct influence of the acid on association of some of these fungi, especially where the inhibited oerganism is favoured by extremes of acidity.

Anaerobiosis and Association of Phytopathogens—

Some observations have been made by previous workers which showed that fungi can respire to a small degree even when free-oxygen is excluded from the culture medium. Bacteria are commonly found growing under anaerobic conditions, but in the case of higher plants, these occurrences appear to be rare. Wherever any growth occurred in the absence of free-oxygen, it has been found that fermentation of sugars replaced the normal respiration found in aerobic plants. It has been found that aerobic bacteria can respire under anaerobic conditions if some fresh, sterile vegetable tissue is added to the culture medium. Aerobic bacteria apparently lack the enzyme peroxidase, which is possessed by anaerobic bacteria and higher plants, and which assists in aerobic respiration. If this enzyme is supplied to the culture, the aerobic bacteria can utilize it and then can respire normally, even though under anaerobic conditions.

An attempt has been made to determine if the rot-producing fungi worked with, respond to a similar treatment. The experiment performed was not an elaborate one, but it was sufficient to show that any of the plant organisms were

TABLE.—XI.—The effect of H-ion concentration on growth of tomato-rotting fungi.

Initial pH	Check	*Cladosporium fulvum*		*C. fulvum* and *Botrytis sp.*		*Botrytis sp.*	
		Final pH	Growth	Final pH	Growth	Final pH	Growth
1.5	1.5	1.5	0	1.5	0	1.5	0
2.2	2.2	2.2	0	2.2	+	2.2	+
2.7	2.7	2.7	++++	2.8	++++	2.8	++
3.2	3.1	2.8	++++	2.9	++++	3.2	++
3.7	3.6	2.6	++++	2.8	++++	3.2	++++
4.2	4.0	2.7	+++	2.7	+++	3.4	+++
4.7	4.5	2.6	+++	2.7	+++	3.0	++++
5.2	5.0	2.5	+++++	2.6	+++++	3.6	++++
5.7	5.4	2.8	+++++	2.6	+++++	3.8	++++
6.2	6.1	2.9	++++	2.8	+++++	3.7	++++
6.7	6.5	2.6	+++++	2.8	+++++	3.8	++++

not able to grow well under anaerobic conditions, even though fresh, sterile, vegetable tissue in the form of raw potato tuber was added to the cultures.

Small test-tubes containing Richard's modified nutrient solution, or with the medium, small cubes of raw potato tuber, washed and sterillized on the exterior with corrosive sublimate, and then cut into cubes with a sterile scalpel, were used for the cultures. Four fungi were used for inoculation purposes, *Penicillium expansum*, *Sclerotinia fructicola*, *Botrytis sp.* and *Cladosporium fulvum*. Two series of cultures were prepared, one containing the potato tissue, while the other only the Richard's medium. The inoculations were made as uniformly as possible, a spore suspension containing about 500 spores per cubic centimeter being used in each. After the inoculations were made, the culture tubes were placed in larger tubes containing some crystalline pyrogallic acid held in position by wads of absorbent cotton. Just before the culture tubes were placed in position in the large tubes, some concentrated caustic patosh (KOH) solution was poured on the pyrogallic acid, The culture tubes were inserted and the large tubes sealed with corks impregnated with melted paraffin. This provided an air-tight chamber from which all free Oxygen had been removed. The cultures were incubated at 20-24°C. for fifteen days, after which period final observations were made.

It was found that in pure cultures of *Penicillium expansum* practically no growth took place. What growth occurred took place during the first three days of the culture period. No difference was found in the cultures containing raw potato tissue.

In pure cultures of *Sclerotinia fructicola* some aerial mycelium was observed but no spores were formed. No stimulus to growth was observed in cultures containing the potato-cubes.

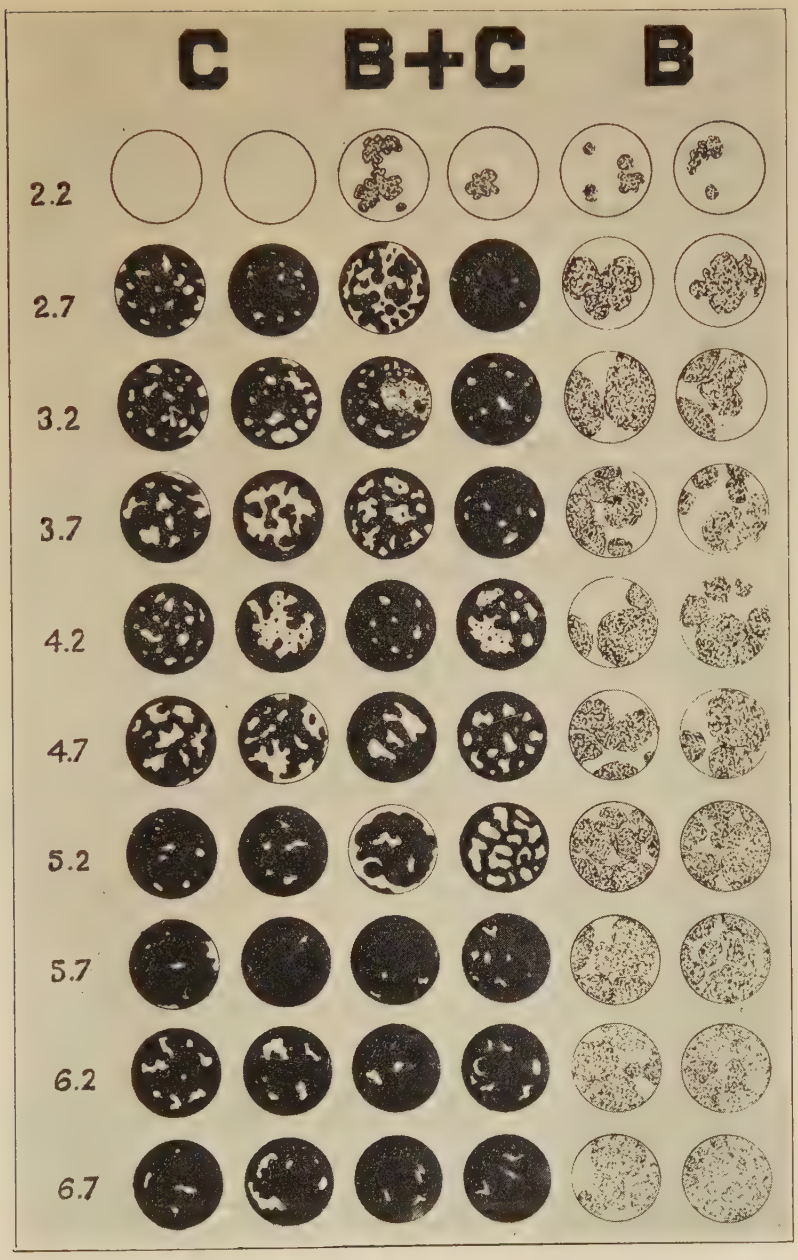

FIGURE XI.—The effect of H-ion concentration on growth of *Botrytis sp.* and *Cladosporium fulvum*, in pure and mixed cultures, Heavy shading represents growth of *C fulvum* (C). and light shading the growth of *Botrytis sp.* (B). Cultures grown at 20-24°C.

In mixed cultures of the above organisms very little growth was found. The Penicillium dominated all the cultures. The addition of the sterile potato did not change the growth characteristics.

In the cultures of *Botrytis sp.* growth of mycelium was slight, and no spores were formed. There was no stimulus to growth given by the addition of the raw potato tissue.

In the pure cultures of *Cladosporium fulvum* very little growth occurred. The potato cubes produced no visible effect on growth.

In mixed cultures the Botrytis dominated, but the growth was no better than in the pure cultures of that organism. The addition of potato did not add to the growth.

After the above observations were made, the culture tubes were exposed to atmospheric oxygen. The effect was immediate. After one day there was a distinct increase in growth in all the cultures, especially in those of Penicillium. Apparently spore germination had occurred in the cultures after they had been placed under anaerobic conditions but no growth occurred. When air was admitted, growth took place at once. The presence of the raw potato cubes did not produce any visible effect on growth, either in the aerobic or anaerobic cultures.

TABLE XII.—The effect of anaerobic conditions on growth of some fungi.

Fungus	Anaerobic cultures 15 days		Aerobic cultures 10 days	
	Rich. mod. medium	Rich. mod. med. plus potato	Rich. mod. medium	Rich. mod. med. plus potato
Penicillium expansum	+	+	++++	++++
Sclerotinia fructicola	++	++	+++	+++
S. fructicola and *P. expansum*	+	+	++++	++++
Botrytis sp	+	+	++++	++++
Cladosporium fulvum	+	+	++++	++++
Botrytis sp. and *C. fulvum*	+	+	++++	++++

The data obtained from the experiment are shown in Table XII.

From the above results the writer concluded that the fungi described above are obligate aerobes. Some respiration probably occurred, nevertheless, for the cultures began to grow as soon as exposed to atmospheric oxygen, which would be delayed if the fungi had to germinate first. There may have been a temporary inhibition in growth due to the absence of free-oxygen, but the cultures were not killed, even after the fifteen day period. As there was no visible effect on growth due to the addition of fresh potato tissue, it is possible that the peroxidase, so useful to aerobic and anaerobic bacteria was not utilized by the fungi, so that the addition of the tissue did no cause any increased growth.

ASSOCIATION OF PHYTOPATHOGENS IN THE HOST.

The effect of host variety

In the study of apple rots, the varieties MacKintosh Red, Fameuse, and McMahon White, were used. All the varieties were found to be susceptible to both *Penicillium expansum* and *Sclerotinia fructicola* ,but the amount of rot was least in another variety of the Russet type. The greatest amount of damage was caused by Penicillium, and except in the variety last named, there did not appear to be any marked difference in the amount of rot in the different hosts.

Pencillium expansum is a parasite which is confined almost exclusively to ripe fruit in storage. No investigations have been made by the writer to determine the amount of rot in fruit less ripe, but a survey of literature failed to reveal any data on the subject.

The Brown rot fungus, *Sclerotinia fructicola*, appears to be able to attack the fruit in any stage of its development. Practically all summer varieties have been reported susceptible to the ravages of the fungus. However, data on the subject of varietal resistence are as yet very meager.

In the case of onion rots, a similar lack of data exists. It has been reported that white and yellow varieties of onions are especially susceptible to *Botrytis allii*. Red varieties appear to be more resistant. These reports have been confirmed by the experiments of the writer. The yellow varieties have been found most susceptible to the invasion of *Botrytis allii* and *B. byssiodea,* but white varieties are more inclined to be attacked by *Botrytis squamosa.*

In the case of tomato only one variety, Livingstone Globe, was used. The amount of rot appeared to be somewhat correlated with the degree of maturity of the plant, the maturity of the fruit, and the amount of shade in which the fruiting plants were growing. Neither *Cladosporium fulvum* nor *Botrytis sp.* attacked the vines prior to fruit formation, even though the young plants were grown under a bell-jar at room temperature. Under green-house conditions, Cladosporium did not appear until after fruit formation had taken place for some time, but Botrytis was found to cause infection as soon as the young fruit had begun to form. The former fungus did not produce an extensive rot in the diseased fruit, confining its activities to the superficial portions. Cracking sometimes occurred in the lesions on the fruit caused by the fungus, and through these wounds *Botrytis sp.* was able to enter and cause the rapid rot. *Botrytis sp.* was found able to cause a rot more rapidly in the green than in the ripe fruit, for in the ripe fruit the fungus was seldom found, or if artificially inoculated, the progress of the rot was very slow.

The Effects of Host Acidity

As mature specimens of the different host plants were used for these experiments, only the data concerning the acidity of these plants at maturity were obtained. However numerous reports have been observed dealing with the

acidity of these hosts, and an attempt has been made to correlate the acidity and amount of infection.

Magness and Diehl (20) have shown that the varieties of apples with which they worked underwent a steady decrease in acidity during the time that they were kept in storage at 32°F. The rate of decrease was nearly the same for all varieties regardless of the original acid content. The varieties in order of decreasing acidity were Rhode Island Greening, Ben Davis, York, Imperial, Winesap, Rome Beauty, and Delicious. The percentage of acid lost during the six months in storage is in reverse order, showing that the varieties with lowest acidity lost the most.

Patrick found that there appeared to be no relation between acidity and sugar content. The range of acid, however, was considerable in the different varieties. The results of his investigations are shown in Table XIII.

An experiment was performed to show the change in acidity due to the action of a rot-producing fungus. The varieties MacKintosh Red, Fameuse, and McMahon White were used for the experiments, and only uniform, sound specimens were used. Often after artificial inoculation it was found that the rot was able to destroy the fruit completely in ten days at room temperature. The H-ion concentration was determined before and after rotting, and it was found that in each case, no matter which fungus, *Penicillium expansum* or *Sclerotinia fructicola* had been used, the acidity of the juice had been increased.

TABLE XIII.—The sugar and acid content of some apple varieties

Variety	Per cent acid	Per cent sucrose	Per cent glucose	Per cent sugar
Soulard Crab	1.124	3.11	5.15	8.26
Scott's Winter	.960	3.06	6.07	9.13
Silken Leaf	.837	1.46	7.87	9.33
Willow Twig	.683	3.87	6.79	10.66
Wythe	.646	2.05	6.83	8.88
Ostrokoff's Glass	.622	1.78	7.68	9.46
Winsted Pippin	.527	1.30	8.33	9.63
Cross	.423	2.12	6.80	8.93
Dorsdorf	.418	2.82	7.48	10.30
Fameuse	.394	3.29	8.31	11.60
Iowa Greening	.117	1.25	7.87	9.12

The above table is quoted from the following reference: Patrick, G. E. Analysis of Apples. Iowa Agric. Exp. Sta., Bull. 3: 82-91, 1888.

The healthy apples, on the other hand, were found to decrease slightly in acidity during the ten-day experimental period. However, as there is little difference in the amount of rot in apple varieties, it is probable that the acid

content is not an important factor determining the development of a rot in a host. The result of this experiment are shown in Table XIV.

In the inoculated onions there was a similar change. The varieties Red Weathersfield, Yellow Globe, and Silverskin were used, and the juice of each differed fron the others only slightly in acidity. The rot caused a definite increase in pH value, bu the checks did not change at all. The results are shown in Table XV.

In the tomato practically no change in the H-ion concentration was observed, although the specimens were completely rotted. *Cladosporium fulvum* produced only a slight rot, which did not affect the acidity of the host at all. *Botrytis sp.* on the other hand, rotted the fruit very quickly, but did not increase the acidity at all.

From the above results it is concluded that acidity is not a limiting factor for the development of a rot in the host by the various pathogenic fungi used. As seen from previous experiments these same fungi are able to grow well at H-ion concentrations greater or less than those of the healthy tissue, so that is not probable that the host acidity could limit the development of the fungus in the host.

Association of Phytopathogens in the Host.

The apple-rotting fungi, *Penicillium expansum* and *Sclerotinia fructicola* have been only rarely found growing together in nature. By means of artificial inoculation of the apple fruit, it is possible to secure association of the two pathogens, but this can be done only if the two organisms are inoculated into the host simultaneously or if the Penicillium is used after the Sclerotinia has already begun to form a rot. No infection was obtained if the latter organism was inoculated into the tissues already attacked by Penicillium.

When both organisms were placed into the artificially created wound at the same time, it was found that both organisms grew and formed the typical rot. The Brown rot, caused by *Sclerotinia fructicola* usually appeared first,

TABLE XIV.—The effect of rotting on the acid content of some apple varieties

Variety	pH of healthy apples		pH of apples rotted by *P. expansum*		pH of apples rotted by *S. fructicola*	
	Initial	Final	Initial	Final	Initial	Final
Fameuse.....	3.1	3.1	3.1	2.8	3.1	2.95
McMahon White.....	3.2	3.9	3.2	2.9	3.2	3.0
MacKintosh Red.....	3.15	3.3	3.15	2.8	3.15	2.9

TABLE XV.—The effect of rotting on the acid content of some onion varieties

Variety	pH of healthy onions		pH of onions rotted by *Botrytis allii*		pH of onions rotted by *Botritis byssoidea*	
	Initial	Final	Initial	Final	Initial	Final
Red Weathersfield.....	5.1	5.1	5.1	5.0	5.1	4.95
Yellow Globe.....	5.2	5.2	5.2	4.8	5.2	4.7
Silverskin.....	5.5	5.5	5.5	5.3	5.5	5.1

and the rot was equal in extent to that produced the single fungus alone. After a few days, however, it was possible to distinguish the lesion caused by the growt of *Penicillium expansum*. It was easy to differentiate between the two rots. The lesion caused by the growth of Sclerotinia is brown at first, black later, but there is no shrinking of the epidermis as the rotted tissue is firm and the apple retains its shape. The rot in this case spreads considerably faster than that caused by Penicillium. This latter fungus appears to have the property of changing the color of the epidermis, so that finally it is the same as when Penicillium alone is responsible for the rot.

A similar change was observed when the apple partially rotted by the Brown-rot-fungus had been inoculated with *P. expansum*. It was noted, moreover, that when *P. Expansum* followed in the wake of *Sclerotinia fructicola*, its progress was slower than when growing alone.

In the apples which had been rotted by *P. expansum* and then inoculated by *Sclerotinia fructicola*, no secondary rot caused by the latter fungus was developed. It is possible that the former fungus was able to suppress the latter completely, the suppression being somewhat similar to that obtained when the two organisms were grown in association in artificial culture.

When each apple had been inoculated by both fungi, but each one placed separately in different wounds on opposite sides of the fruit, the fungi produced their characteristic rots around the point of infection. There was no reduction in the rate of spead until the borders of the lesions approached each other. When the two rots began to merge, *Sclerotinia fructicola* did not advance into the rotted tissue produced by Penicillium, but this fungus was able to invade the rotted tissue produced by Slerotinia, though at a diminished rate. The growth of the lesion could be observed by making surface markings along the borders of the lesions at regular intervals.

The above phenomena were somewhat modified by temperature. It was found that at 30-34°C. no rot was formed by Penicillium, but the Sclerotinia was able to rot the apple nearly as rapidly as at room temperature, 20-24°C. At this latter tempeature both fungi grew well and were able to rot the apples in a

short time. At 4-8°C. the growth of both fungi in the host was very much reduced, so that the amount of rot was reduced in proportion. A more detailed account of the effect of temperatre on growth and association will be given below.

In the onion-rotting fungi, *Botrytis allii* and *B. byssoides*, the former grew much faster at the highest and medium temperatures named above. In the lowest tmperature the latter fungus grew best. When growing together in the same host it was found that *B. allii* usually produced its own characteristic rot, while the other fungus did nor develope at all. This result was not modified by changes in temperature though in pure culture the *B. byssoidea* was able to produce a rot of the onion through its own activity. The color of the onion did not make any difference in the growth of the associated organisms.

In tomatoes it was impossible to obtain large lesions by inoculations of the fruit with *Cladosporium fulvum* even though rotting has been observed in the greenhouse. The inoculated fruit was kept at 20-24°C. for a long period, and though rots initiated by*Botrytis sp.*, soon developed, and caused a rapid destruction of the tomato fruit, the Cladosporium grew slowly. Therefore, when the two fungi were in association on the same host, the rot, caused by Botrytis always formed. This is contrary to the results obtained when the fungi were grown in artificial culture. See Figure XI.

Effect of Temperature on Association:—

As temperature appears to have a distinct influence in the development of phytopathoges in artificial culture, it is probable that similar effects are felt by rot-producing fungi when growing on their hosts. The following experiments were made to demonstrate the effects of temperature on the presence or absence of a typical rot.

In the study of apple rots, apples of the same size, maturity, and variety, were selected. The volume of the apple in each case was determined by the water-displacement method. After the end of the incubation period the diseased tissue was scraped out and the volume of the healthy tissue determined. The difference between the two volumes showed the amount of rot produced by a definite fungus in a certain set of conditions. It was found that even in the healthy apples a small amount of shrinkage occured, and this was determined by the use of punctured but unicoculated checks.

In a preliminary experiment the varieties MacKintosh Red and McMahon White were used. Six apples of each variety were inoculated with spores of *Penicillium expansum* or *Sclerotinia fructicola* or both. After incubation at 20-24°C., for seven days the rotted tissue was scraped out from each inoculated apple and the amount rotted measured. It was found that the rots developed well in both varieties, but in the McMahon White the percentage of rot was

greater than in MacKintosh Red. In each case the Slerotinia produced a greater amount of rot than did the Penicillium. The results are shown in Table XVI.

In a second experiment, only the variety MacKintosh Red was used. The same fungi were used, but the rots were incubated at 30-34°C., 20-24°C., and at 4-8°C. The period of incubation extended over ten days after which the amount of rot was determined in each case. The results are shown in Table XVII, and Figure XII.

In a third experiment the variety Fameuse was substituted for MacKintosh Red, but otherwise the experiment was the same. The data obtained are shown in Table XVIII.

In the study of onion rots the procedure used above could not be adopted, on account of the uneven distribution of the rot in the tissues of the host, and also because the decaying tissue was not easily separated from the healthy. The relative rate of rotting could be therefore determined by external examination only, and so this method was used in obtaining the data. The development of each fungus in the host is shown in Figure XIII, where the rots produced by pure and mixed cultures of the above onion-rotting fungi at different temperatures are shown. The growth of the rot in all cases was very slow, for it took nearly four weeks to rot each bulb, even at the optimum conditions for the rot development.

TABLE XVI.—Amounts of tissue rotted by apple-rotting fungi in two varieties.

Fungus	Initial volume	Volume healthy after 10 days	Volume rotted	Percentage rotted
Variety McMahon White :				
S. fructicola	240	115	125	52.4
P. expansum	225	150	75	33.3
Variety MacKintosh Red :				
S. fructicola	77	43	34	44.3
P. expansum	103	80	23	22.5

In the checks the shrinkage in volume was about 5 c. c. in McMahon White where the apples were on the average 226 c. c. in volume, and 2 c. c. in MacKintosh Red where the apples averaged 93 c. c. All volumes in the above table are in cubic centimeters.

TABLE XVII.—Effect of Temperature on amount of rot in the apple variety Mackintosh red.

Fungus	Initial vol. before inoculation	Final healthy volume	Amount rotted	Per cent rotted
Incubator Temp. (30-34oC.)				
S. fructicola	147.5	62.5	85.0	57.6
S. fructicola and *P. expansum*	140.0	102.5	37.5	26.7
P. expansum	137.5	133.0	0.0	0.0
Room Temp. (20-24oC.)				
S. fructicola	135.0	0.0	135.0	100.0
S. fructicola and *P. expansum*	130.0	25.0	105.0	80.0
P. expansum	125.0	62.5	62.5	50.0
Cold Storage Temp. (4-8oC.)				
S. fructicola	142.5	140.5	0.0	0.0
S. fructicola and *P. expansum*	111.0	108.0	3.0	2.7
P. expansum	147.5	142.5	5.0	3.4

In the checks the following shrinkage was observed:
At 30-34oC. shrinkage from 139 to 135 c. c. or 4 c. c.
At 20-24oC. " " 137 to 133 c. c. or 3.5 c. c.
At 4-8oC. " " 134 to 132 c. c. or 2.0 c. c.
All volumes are given in cubic centimeters.

TABLE XVIII.—Effect of Temperarure on amount of rot in the apple variety Fameuse

Fungus	Initial vol. before inoculation	Final healthy volume	Amount rotted	Per cent rotted
Incubator Temp. (30-34oC.)				
S. fructicola	120.0	19.0	101.0	84.1
S. fructicola and *P. expansum*	121.0	13.0	108.0	89.2
P. expansum	123.0	120.0	3.0	2.4
Room Temp. (20-24oC.)				
S. fructicola	103.0	10.5	92.5	89.8
S. fructicola and *P. expansum*	109.5	15.0	94.5	86.3
P. expansum	111.0	66.0	44.5	40.1
Cold Storage Temp. (4-8oC.)				
S. fructicola	114.0	111.0	3.0	2.6
S. fructicola and *P. expansum*	116.0	102.5	13.5	11.6
P. expansum	124.0	120.0	4.0	3.2

In the checks the following shrinkage was observed:
At 30-34oC. shrinkage from 119.0 to 113.0 or 6.0 c. c.
At 20-24oC. " " 104.0 to 101.5 or 2.5 c. c.
At 4- 8oC. " " 113.5 to 112.0 or 1.5 c. c.
All volumes are given in cubic centimeters.

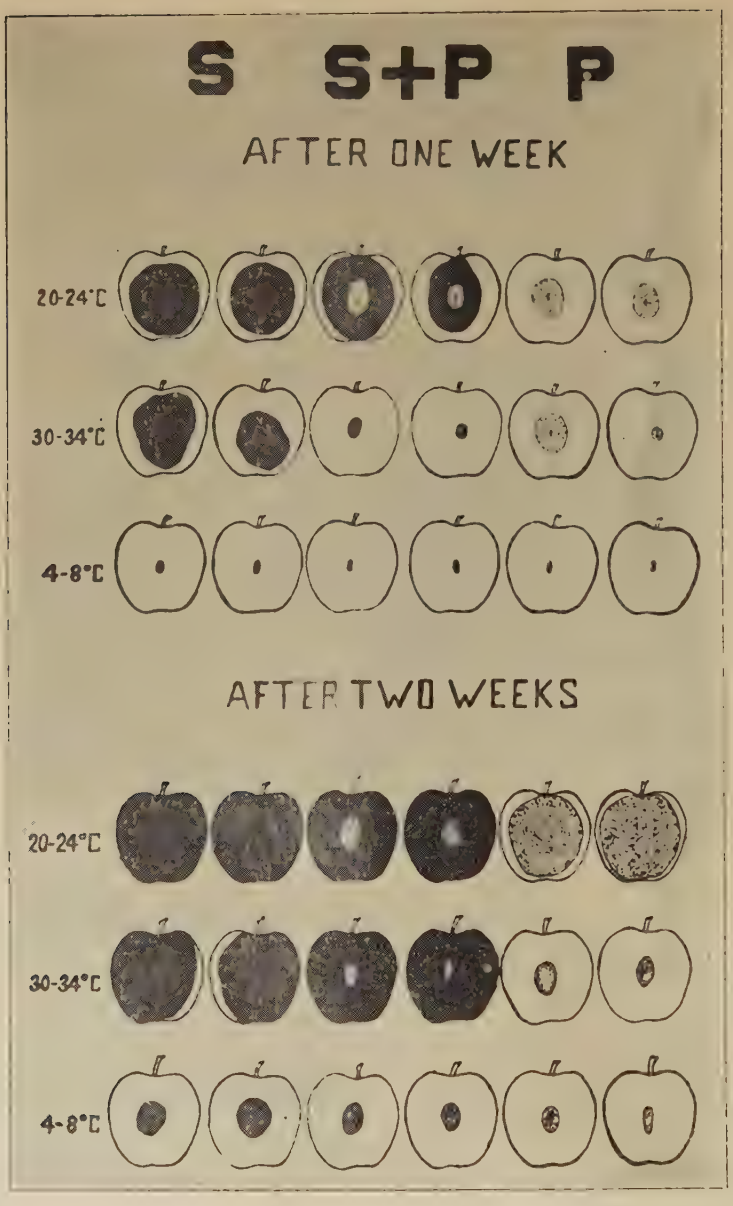

FIGURE XII.—The influence of temperature on the development of apple rots caused by *Penicillium expansum* (P) and *Sclerotinia fructicola* (S) grown in pure culture or in association. Heavy shading shows growth of *S. fructicola*, light shading that of *P expansum*. Note dominance of the former in mixed culture.

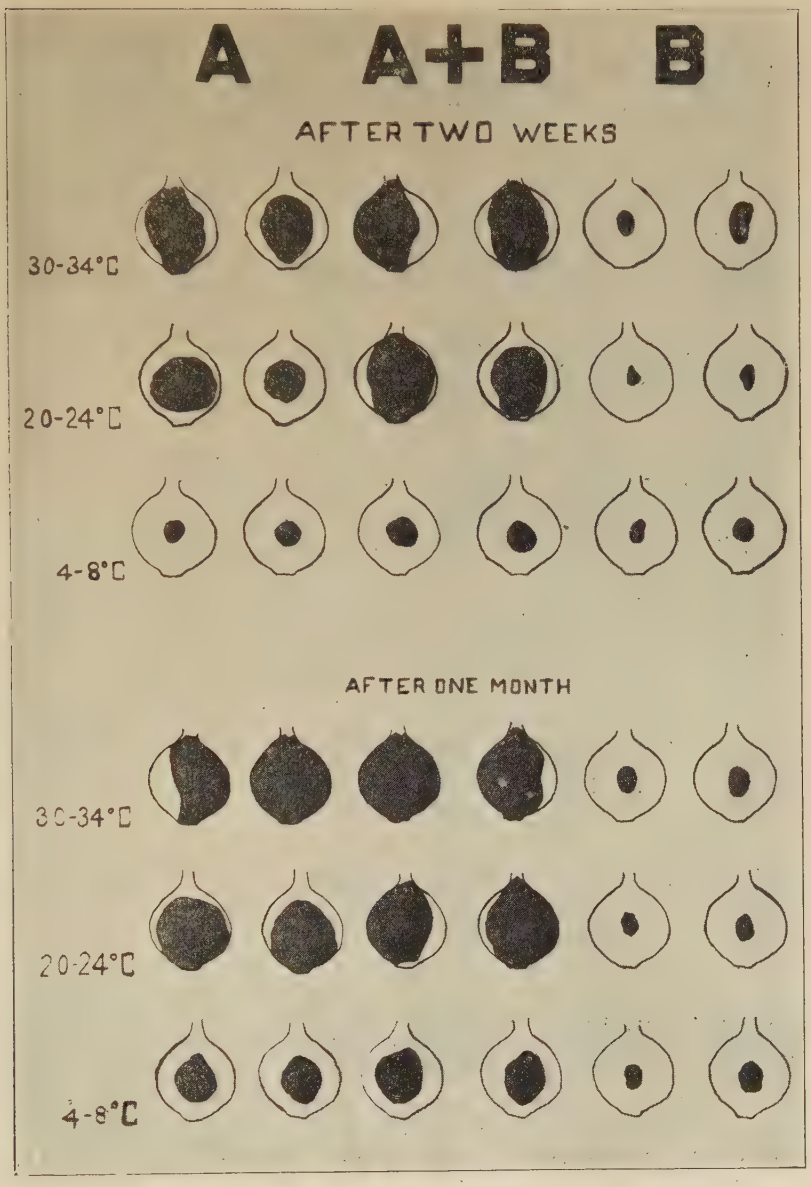

FIGURE XIII. The influence of temperature on the development of onion rots caused by ***Botrytis Allii*** (A) and ***Botrytis byssoidea*** (B) when grown in pure culture and in association.

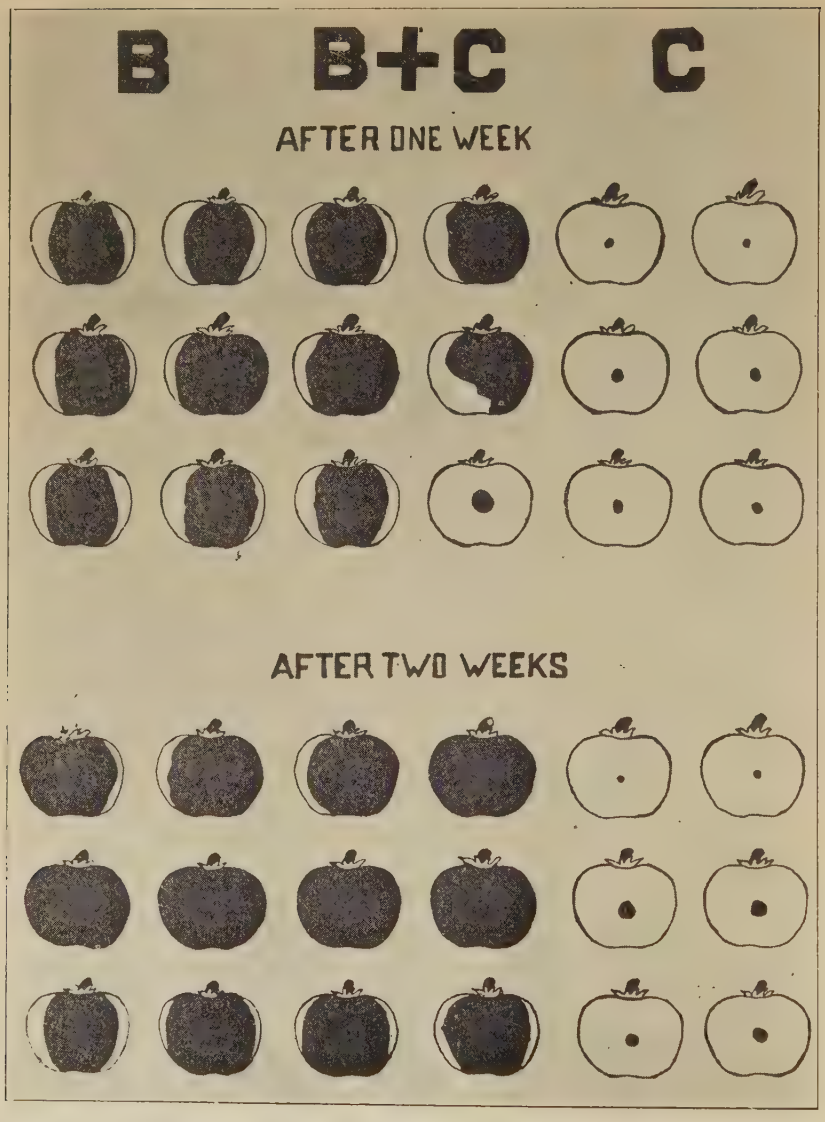

FIGURE XIV.—The influence of temperature on the development of tomato rots caused by *Botrytis sp.* (B) and *Cladosporium fulvum* (C) when grown in pure culture and in association.

For the tomato rots charts similar to those showing the onion rots were prepared. A difficulty in determining the amount of rot was encountered here also. It appears that though externally a small lesion is produced by *Botrytis sp* the entire interior of the fruit of the tomato becomes softened by the activities of the fungus, and so the exact line of demarcation cannot be determined. Therefore the growth of the lesion on the surface of the fruit was used as the index of the rate of progress of the fungus. The results are shown in Figure XIV.

Again, attention is drawn to the fact that temperature appears to be a limiting factor which determines the amount and kind of rot that developes when the rot-producing fungi are grown separately or in association on the host. Practically similar results are obtained when the fungi are grown on the host or in culture, with several important exceptions. It has been true that Cladosporium dominated Botrytis in culture, but the reverse is found when they are on the host.

Summary and Conclusions

The phytopathogens used in the experimental work during this investigation were those responsible for rots of stored fruits and vegetables, and of greenhouse tomatoes.

Association of phytopathogens has been observed in a large number of hosts. These pathogens may be associated with others, or with saprophytic organisms which usually follow the pathogens in their advance through the host tissues. The relations in all cases are complex.

Even though the pathogens may produce a certain result in artificial media, a totally different result may occur on the host.

Association of phytopathogens in artificial media may produce different results when different organisms are associated, those results being controlled by several factors, such as temperature, H-ion concentration, the amount of inoculum. When in the host, the results are controlled by the temperature, and the order in which the infections take place.

Several types of association exist: (1) when one organism causes complete inhibition in artificial media; (2) when there is mutual tolerance between the associated organisms on culture media; (3) when one organism may inhibit the second in artificial culture, but when the same fungus is present on the host, it may be slow in development, and it follows in the second's wake.

The H-ion concentration has no marked influence upon association, although sometimes the inhibited organism can grow in a culture medium of which the H-ion concentration is such as prevents the growth of the inhibiting organism.

Temperature is a limiting factor in association of phytopathogens. Usually the results are similar when two organisms are grown together on the host or in mixed culture on artificial media. The temperature can sometimes be favour-

able to the inhibited organisms so that they can grow well, where at ordinary temperatures, 20-26°C. they may be totally suppressed. Therefore it may be expected that the rate of rot can be compared to the rate of growth in culture, and where two pathogens are associated in the host the one most suited to grow at a given temperature may dominate and produce its own characteristic rot.

The amount of inoculum in artificial culture is another limiting factor. One organism may become completely suppressed if the amount of the inoculum of the second is in excess of the first, or in other words, an inhibited organism is able to grow well if the inoculum of that organism is in excess of the inoculum of the inhibiting organism. The latter can also grow in the mixed culture and eventually prevents the growth of its weaker associate.

The inhibition of one organism by another is found to be due to some toxic substance other than acid. An analysis is required to show the nature of these toxic substances. Some of the inhibition of growth may be due to acidity of the medium or to the unequal assimilation of available foods from the media by the organisms growing on it.

The addition of vegetable extract does not cause any visible increase of fungous growth, although a more positive result is obtained in bacterial cultures to which this extract has been added.

The phytopathogens studied in the course of the above investigations were unable to grow well in the absence of free-oxygen. The addition of peroxidase in the form of sterile, raw, potato tuber tissue did not change this condition, though in cultures of aerobic bacteria the addition of peroxidase from this source allowed growth to take place.

Spore germination has been found to be affected by temperature, H-ion concentration, and the type of medium. Spore germination is decreased when the above factors are extreme.

1. Adams, J. F. Darluca on *Peridermium Peckii*. Mycologia 12: 309-315, 1920.
2. Ames, Adeline. The Temperature Relations of Some Fungi Causing Storage Rots. Phytopath 5: 11-19, 1915.
3. Balls, W. S. Temperature and Growth, Ann. of Bot., 22: 557-559, 1908.
4. Bottomley, W. B. Some Effects of Organic Growth-promoting Substances (Auximones) on the Growth of *Lemna minor*, Proc. Roy. Soc. Lond., 89-102, 481, 1917.
5. Boyle, C. Studies on the Physiology of Parasitism X, The Growth Reactions of Certain Fungi to thier Staling Products, Ann. of Bot. 38: 113-135, 1924.
5. Brooks, C. and Cooley, J. S. Temperature Reletions of Apple Rot Fungi. Jour Agric.. Res. 8: 138-164, 1917.
7. Brown, W. Experiments on the Growth of Fungi in Culture Media. Ann. of Bot. 37: 105-129, 1923.
8. Cook, M. T. Succession of Fungi on Culture Media. Amer. Jour. Bot. 11: 94-99, 1924.
9. Duggar, B. M. Physiological Studies with Reference to the Germination of Certain Fungus Spores. Bot. Gaz. 31: 38-66, 1901.
10. On the Toxic Effect of Deleterious Agents on the Germination and Growth of Certain Filamentous Fungi. Bot. Gaz. 28: 289-327, 378-404, 1897.
11. Faulwetter, R. C. The Alternaria Leaf Spot of Cotton. Phytopath, 8: 106-113, 1918.
12. Haynes, D. Chemical Studies on the Physiology of Apples I. Changes in Acid Content and Its Physiological Significance. Ann. of Bot. 38: 72-96, 1925.
13. Heald, F. D., and Pool, V. W. The Influence of Chemical Stimulation upon the Production of Perithecia by *Melanospora pampeana*. Nebr. Agr. Exp. Sta. Bull, 269, 1925.

14. Hunter, O. W. The Production of a Growth-Promoting substance by Azotobacter. Jour. Agric. Res. 23: 825, 1923.

15. Itano, A. Physiological Study of *Azotobacter chroococcum*. Jour. Bact. 8: 483, 1923.

16. Johnson, J. and Harlan, W. Relation between H-ion and the Salt Concentrations and the Growth of Seven Soil Moulds. Research Bull. 76. Iowa Agric. Sta.

17. Kostychev, A. Kostychev's Plant Respiration: 86-96, 1924.

18. Linossier, G. Les Vitamines et les Champignons. Compt. Rend. Soc. Biol. 82: 381-384 1919.

19. Lepeschkin, W. The Influence of Vitamines upon the development of Yeasts and Moulds. Amer. Jour. Bot. 11: 164-167, 1924.

20. Magness, J. R. and Diehl, H. C. Physiological Studies of Apples in Storage. Jour. Agric. Res. 27: 1-35, 1910.

21. Millard, W. A. and Taylor, W. Antagonicm of Micro-organisms as a Controlling Factor in the Inhibition of Scab by Green-manuring. Ann. Applied. Biol. 14: 202, 1927.

22. Munn, M. T. Neck Rots of Onions. New York Agric. Exp. Sta. Bull. 437, 1927.

23. Porter, C. T. Concerning the Characteristics of Certain Fungi as Exhibited by Their Growth in the Presence of Other Fungi. Amer. Jour. Bot. 11: 168-188, 1924.

24. Robbins, W. J. Isoelectric Points for the Mycelium of Fungi. Jour. Gen. Physiology. 6: 259-271, 1924.

25. Scott, I. T. The Influence of H-ion Concentration on the Growth of *Fusarium lycopersici* and on Tomato Wilt. Miss. Agric. Coll. Res. Bull. 64.

26. Walker, J. C. Botrytis Neck-rots of Onions. Jour. Agric. Res. 33: 893, 1926.

27. Thoytta, T. and Avery, O. T. Studies of Bacterial Nutrition. Jour. Exper. Med. 39: 455, 1921.

28. Webb, R. W. Studies on the Physiology of Fungi. X.Germination of the Spores of Certain Fungi in Relation to H-ion Concentration. Ann. Miss. Bot. Gard. 6: 201-222, 1919.

29. Weston, W. A. R. The Incidence and Intensity of *Puccinia glumarum* on Wheat Infected and Non-infected with *Tilletia tritici*, Showing an Apparent Relationship between Rust and Bunt. Ann. Appl. Biol. 74: 105-112, 1927.

30. Young, V. H. Toxic Substances Produced by Fungi. Annual Rept. Mich. Acad. Scie. 22: 205-208, 1920.

31. Zeller, S. M. and Schmitz, H. Studies in the Physiology of the Fungi. VIII. Mixed Cultures. Ann. Miss. Bot. Gard. 6: 183-192, 1919.

THE EFFECT OF BORDEAUX MIXTURE ON THE YIELD OF POTATOES DURING THREE BLIGHT-FREE YEARS

H. N. Racicot, Pathologist-in-charge

Laboratory of Plant Pathology, Ste-Anne de la Pocatiere, Que.

Although it was known that there is very little late blight in the eastern part of Quebec, an experiment on spraying was begun in 1924 to determine the number of applications necessary to control late blight in this district, the best time to make these applications, and also the effect of Bordeaux mixture upon the yield in blight-free years.

Each plot consisted of eight 25 ft. rows, making eight replications, to equalize any difference in the soil. One plot was unsprayed, and the other plots were sprayed 4 or 6 times beginning June 30, July 20 or August 10. The Green Mountain variety was used throughout this experiment.

In 1925 and 1927, only a mere trace of late blight occured, the amount being so small that it could not be recorded as percentage, and these years are considered blight free. In 1926, late blight was entirely absent.

TABLE 1.—Results of Spraying in 1925

Plot	No. & time of sprayings	Yield, bus. per acre	
		Total	Marketable
1	Control, unsprayed	235	134
2	4, beginning June 30	249	135
3	6, " June 30	253	143
4	4, " July 20	261	151
5	6, " July 20	258	143
6	4, " Aug. 10	255	149
7	6, " Aug. 10	271	161
Average increase in yield of plots 3 and 4 over plot 1		22 (9.3%)	13 (9.6%)
Average increase in yield of plots 5, 6 and 7 over plot 1		26 (11. %)	17 (12.6%)
Average increase in yield of sprayed plots over unsprayed plot		23 (9.7%)	13 (9.6%)

In 1925, very dry weather occured throughout August and the first ten days of September. The vines of the plots that were not sprayed during the

drought period suffered considerably, most of the plants drying up before the fall rains came. The vines sprayed during the dry period were still green when the rains came in September, and they gave higher yields. Plot two was only sprayed during July, before the drought, and gave no better yield than the unsprayed plot. Plot 3 and 4 were sprayed twice during the early part of the dry period, and plots 5, 6 and 7 throughout most of the dry weather, and these gave the largest yields.

In 1926, the dry weather occured during July and the first of half August much earlier than in 1925.

TABLE 2.—Results of Spraying in 1926.

Plot	No. & time of sprayings	Yield, bus. per acre	
		Total	Marketable
1	Control, unsprayed	172	114
2	4, beginning June 30	233	166
3	6, " June 30	203	146
4	4, " July 20	169	117
5	6, " July 20	185	136
6	4, " Aug. 10	168	127
7	6, " Aug. 10	147	97
Average increase in yield of plots 2 and 3 over plot 1		46 (26.7%)	42 (36.8%)
Average increase in yield of plots 4 and 5 over plot 1		5 (2.9%)	12 (10.5%)
Average increase in yield of plots 2, 3, 4, 5 and 6 over plot 1		19 (11. %)	24 (21. %)

Plots 2 and 3 were sprayed during the period of drought and gave the highest yields. Plots 4 and 5 were only sprayed during the latter part of the dry weather and did not give as good a yield as plots 2 and 3, but better than plot 1. Plots 6 and 7 were only sprayed after the drought and did not give any better yields than plot 1. No. explanation can be found for the low yield of plot 7.

In 1927, there was just enough rain throughout the summer to produce good growth and yet not enough for late blight to develop. The sprayed plots gave a slight increase in yield, an average of 12 bushles per acre, over the unsprayed plots.

TABLE 3.—Results of Spraying in 1927.

Plot	No. & time of sprayings	Yield, bus. per acre	
		Total	Marketable
1	Control, unsprayed	344	278
2	4, beginning June 30	351	289
3	6, " June 30	351	287
4	4, " July 20	370	303
5	6, " July 20	347	285
6	4, " Aug. 10	375	306
7	6, " Aug. 10	343	274
Average increase in yield of sprayed plots over unsprayed plots		12 (3.5%)	12 (4.3%)

TABLE 4.—Average results of Spraying for the three blight-free years.

Plot	Treatment	Yield, bus. per acre	
		Total	Marketable
.....	Unsprayed	250	175
.....	Sprayed	268	191
Increase in yield of sprayed over unsprayed		18 (7.2%)	16 (9.1%)

Spraying potatoes during three blight-free years gave an increase in yield over unsprayed potatoes of 16 bushels of marketable tubers per acre. This more than pays the cost of spraying, and is an insurance against the sudden appearance of late blight.

Potatoes sprayed during periods of drought survive better than unsprayed potatoes, and are able to produce a better crop when the fall rains come.

RASPBERRY INSPECTION IN QUEBEC IN 1927

H. N. Racicot, Pathologist-in-charge

Laboratory of Plant Pathology, Ste-Anne de la Pocatiere, Que.

A survey was made in 1925 of a number of raspberry plantations in different parts of the province. A great deal of disease was found in most of the plantations visited. The raspberry canes obtained by growers to set out new plantations contained in most cases a high percentage of disease. Therefore, the inspection and certification of raspberry plantations was inaugurated in 1926 in order to enable growers to place good stock on the market.

In 1927, sixty-five inspections were made, and thirty three plantations were certified. Of the different varieties there were 21 Herberts inspected and 17 certified, 21 Newmans inspected and 12 certified, 19 Cuthberts inspected and one certified, and three of unknown variety inspected. The Cuthbert plantations were all on the Isle of Orleans. The results of the inspection of 1926 and 1927 are given in Table 1. A summary of the diseases present in the plantations inspected in 1927 is given in Table 2.

TABLE 1.—Results of Raspberry Inspections.

Year	No. of inspections	No. cert.	% cert.	Herbert		Newman		All other varieties	
				Insp.	Cert.	Insp.	Cert.	Insp.	Cert.
1926	31	7	23	6	2	20	5	5	0
1927	65	33	51	21	17	21	12	20	4

Insp. — Inspected.
Cert. — Certified.

TABLE 2.—Diseases on varieties Inspected in 1927.

Variety	Mosaic			Leaf Curl			Spur-Blight		
	Max.	Min.	Aver-age	Max.	Min.	Aver-age	Max.	Min.	Aver-age
Herbert	12	0	2.5	.....	.....	.....	Moder-ate...	Trace..	Slight..
Newman	50	Trace..	7.3	.....	.....	.....	.....	Trace.	
Brighton	.....	.....	1						
Cuthbert	100	0	6	100	1	40			
Unknown	2	Trace.	1						

Max. — Maximum. Min. — Minimum.

The increase in the percentage of plantations certified in 1927 over those certified in 1926, as indicated in Table 1, is due to two reasons. First, because many of the plantations inspected in 1926 were young plantations, and these were thoroughly rogued, enabling them to pass the inspection in 1927. Second, because there was very little spur-blight in 1927, allowing many more Herbert plantations to be certified than in 1926.

The good results already obtained, in as much as a number of plantations were thoroughly cleaned up, justifies this service. The standards adopted were not high, nor were they rigidly adhered to, but as the plantations become more free from diseases, they shall be raised accordingly.

THE CUCUMBER GALL

By Omer Caron, B.S.A., Botanist Department of Agriculture, Quebec.

Occurence and economic importance.

I wish to draw the attention of the members of this society to a disease of cucumbers and melons which caused a considerable amount of damage in different parts of the province during 1927. This is the cucumber gall which we found at Sorel and in the neighbourhoods of Montreal and Quebec. The disease is apparently quite rare as there are few references to it in the phytopathological literature.

The occurence of the disease at Sorel was brought to my attention in 1925, but I was unable to devote any time to it until the latter part of the summer of 1927. At the Sorel farm on which it was discovered nearly the whole crop was lost last year.

On the 15th of December I spoke on this disease before the market gardeners' society. At the close of the address I was informed by one of the members that he had lost a great part of his melon crop through this disease. Specimens have been sent me from Deschambault, St. Augustin and Beauport near Quebec. In the last mentioned town last September it was almost impossible to find clean marketable fruit. It will be seen that the disease is well established and of considerable economic importance.

Symptoms.—

A good description of the disease is given in Chupp's "Manual of Vegetable Garden Diseases" and it was with the aid of this that we were able to identity it.

There is little evidence of the disease on the leaves, and it is necessary to examine the stems and the young fruits to see the work of the fungus parasite. Here and there on the young fruit will be seen, during the early stages of the attack, dark spots with drops of a viscous fluid. A few days later there grows out from these spots a white mycelium which soon becomes covered with an olive-green powder. At first sight the lesions resemble the common mouldy spots made by a Penicillium.

If the infection is heavy these spots which are about one-eighth of an inch in diameter spread and fuse until they cover the entire fruit, causing it to rot. In light infections the fruit does not die but becomes deformed. The rot may be due to a secondary bacterial infection, but as so often happens in gall infections, the disorganisation of the tissues by the gall fungus makes it possible for the secondary organism to enter. Beneath the spots the flesh sinks in so that the lesions become depressed.

On melons the symptoms are slightly different, the spots are larger and the fruit does not mature as in the case of the cucumber.

The organism:—

The fungus always present in the lesions is a *Cladosporium* of the Fungi Imperfecti, the species is probably *C. cucumerinum* Ell. & Arth. The identifiy of the organism has been confirmed by Dr C. L. Shear of Washington.

Pure culture:—

The fungus is saprophytic normally and only occasionally parasitic, so that it develops well on the ordinary culture media. I have not had time to study its physiology but it evidently retains its vitality in pure culture for a long time. Thus the tubes which I have here were transferred from a seven months culture. The growth of the myceliym is very rapid and the entire cycle may be passed through in three or four days. Ordinary changes of temperature do not affect the development noticeably.

Inoculations:—

The pure culture was not obtained until September and in the absence of a greenhouse for winter experimentation I was unable to complete my observations. I have howeer succeeded by inoculations in producing lesions resembling the original ones on old cucumbers. This has established the relation between the organism isolated and the disease. It has also proven that the same organism is responsible for both the melon and the cucumber disease.

Control:—

Owing to the lateness of the season it was impossible to carry on control experiments. One would expect however that the fungus would be controlled readily by the common fungicides, especially by Bordeaux mixture dry or liquid. Failure to control it in 1927 was probably due to the fact that the application should be made below the leaves since it is the stems and fruit rather than the foliage that are attacked. The application should be repeated at intervals of about a week as the fungus develops very rapidly.

I present these incomplete notes to you knowing that they do not constitute an interesting biological study, but rather to sound a note of warning concerning this disease which has been introduced into the province and which may cause serious damage during damp seasons such as that of last year.

A PRELIMINARY NOT E ON A NEW METHOD OF ERADICATING MUSTARD IN GRAIN FIELDS

By Omer Caron, B.S.A., Botanist, Department of Agriculture, Quebec.

Various chemical treatments have been recommended for killing wild mustard in grain fields, but of these the salt water treatment is cheapest, easiest to apply and gives as good results as any. This method was first used by L. Roy a French agronomist of Besançon some three of four years ago.

This communication represents a report on one year's trial of this method applied according to the recommendations of its discoverer. We did not consider it necessary to repeat the preliminary tests, nor do we hesitate to communicate the results although based on a single year's work, since they corroborate the results of other workers.

We were naturally somewhat diffident in undertaking this work since spraying with salt was a new experience to us, but the results obtained at the nursery farm of Deschambault were so satisfactory that we considered that they should be made known. So far the work has been done on a small scale, but next year we hope to extend it very considerably, and to be able to present a detailed report of our results at a subsequent meeting of this society.

To day I wish only to point out to you the conditions which the author considers as most suitable in carrying out this treatment and which proved quitc satisfactory with us. The directions given are very important and should be followed carefully.

1. The method is recommended for the destruction of all wild crucifers. Our trials were made on the wild mustard, *Brassica arvensis.*

2. The application should be made when the grain is six or eight inches high. At this time the mustard plants form rosettes on the surface of the soil. The application should be made before the flowers appear.

3. A thirty percent solution gives best results, that is about three pounds to the gallon of water. The solution is applied at the rate of one gallon to 400 square feet, or about 110 gallons per acre.

4. The application should be made on a warm bright day between ten a. m., and noon. The author clains that at this time the mustard plants are at their greatest vegetative activity and offer least resistance to the action of the salt. The application should be made with a sprayer rather than a watering can.

5. There is no danger of burning the grain, The ends of the leaves turn slightly yellow, but at the end of a week this has disappeared. The rosettes of the mustard rust and die within twenty-four hours.

6. The water absorbed by the soil is not harmful. In small quantities salt stimulates growth. Any excess is carried off by drainage.

In conclusion I may repeat that this method is easy to apply. It is inexpensive and costs less than weeding a field. The cost might be further reduced where a cheap coarse salt is available.

AN ENEMY OF THE LILAC

By C. B. Hutchings, Entomological Branch, Department of Agriculture, Ottawa.

The introduction into Canada of the lilac leaf-miner, *Gracilaria syringella* Fabr., in all probability has taken place in very recent years through the importation of European nursery stock of which lilacs and deutzias form a considerable part.

Any unjury this insect may have caused previous to 1923 when it was first discovered in Canada, does not appear to have attracted any attention, nor could any mention of it be found in either Canadian or United States records up to that time. During the summer of 1923, however, the larvae were observed for the first time in Ottawa. In August of that year the writer happened to be passing one day through the grounds of the Victoria Museum and noticed that the lilacs there appeared to be very unthrifty. Upon closer examination it was found that a leaf-miner was responsible for the injury. A brief survey of the lilac bushes in that neighbourhood revealed the fact that a large number of them were affected in the same way. Specimens taken were identified as *Gracilaria syringella* Fabr. and proved to be the first record of their kind for Eastern Canada.

The same year Professor Caesar, Provincial Entomologist for Ontario, in his report "Insects of the Season",stated that he had received several complaints from Guelph, Newcastle and Toronto about lilacs being injured by a small caterpillar. This insect proved later to be the lilac leaf-miner. Since that year the pest has spread rapidly and is now established in Ottawa, Toronto, Guelph and other places in western Ontario.

A glance at the European records of *Gracilaria syringella* Fabr. shows that investigators there consider this insect a serious pest on all lilacs. It is reported to attack also deutzia, spindle tree, privet and ash, but according to our Canadian records, up to the present time, it has been found only on lilac.

From our studies of the life-history made during the summer of 1924 and since, we have found there are two generations—the first early in the season and the second about midsummer. Pupation occurs on the ground in the leaf litter, and the moths emerge therefrom about the third week in May. Eggs are deposited in small groups on the underside of the leaves near the axils of the midribs and larger veins. At first, the young larva works as a miner aud indicates its presence in the leaf by a small reddish-brown spot. Not infrequently several larvae will be found working together in the same location and with the coalescing of the mines the leaf soon becomes bladdery and shrivelled. After three weeks the larvae leave the mines, come to the exterior and begin rolling the

leaves. The roll is usually made from the tip inwards, (though side rolling is also common) and is held down by strong, thick, silken bands. Feeding takes place from within the roll, several larvae often being together on the same leaf.

In about two weeks the larvae mature, let themselves to the ground by a fine thread and pupate there among the rubbish and surface soil.

The amount of time required to complete the entire life-history is about two months.

The second generation follows in a fortnight and is ready to emerge about the end of July or beginning of August. Their attack is more severe than that of the first generation; consequently by the end of September there is little green foliage left on the bush.

For the benefit of those who are not familiar with this insect, the following brief description may be of some assistance:—

The adult is a very small dark-brown moth about $\frac{3}{16}''$ long, with a wing expanse of $\frac{3}{8}''$. The upper wings are brown and crossed with six irregular, yellow patches, while the under ones are grey-brown and fringed. The moths are active during the twilight hours.

The caterpillar when fully grown is $\frac{5}{16}''$ long, $\frac{1}{16}''$ broad, dull glassy in apparance and spindle-shaped. The head is smooth, conspicuous and of a decided brown colour. There are several long hairs near the last segment of the abdomen.

The pupa, which is enclosed in a thin cocoon of white silk, is about 3|16″ long and of a yellowish cast. Though difficult to locate it may be found hidden away amongst the ground litter attached to dead leaves, bits of soil and such like material which may afford convenient surface for adherence.

In our control experiments we have obtained satisfactory results from the use of nicotine sulphate. This material applied in the proportion of 1½ tablespoonfuls to each gallon of water, kills the young larvae in the mines and also the older ones in the rolls. The best time to apply the mixture is early in June when the leaves begin to show the spots. A second application should follow a fortnight later if the spots continue to appear, In cases where the leaf-rolling stage has been reached it may be well to strengthen the solution slightly. The addition of a little soap will help the material to adhere to the foliage much better. The spray should be fine and thoroughly applied, especially to the underside of the leaves. It is also advisable, when convenient, to pick and destroy in the early season any spotted leaves noticed on the tree. Much good can be effected in this way.

PHYSIOLOGICAL STUDIES OF CELLULOSE FERMENTATION

J. R. Sanborn Ph.D. Department of Bacteriology Macdonald College, P.Q.

Observations of cellulose destruction in nature reveal the fact that agents of tremendous significance are rapidly decomposing recent vegetation and older plant residues. In soil, compost heaps, manure piles, septic tank, stagnant water, and sludge deposits, evidences of the rapidity and completeness of this process are particularly apparent.

The secrets of rapidity and efficiency, however, rest with nature. Man's attempts to study cellulose fermentation in the laboratory have been woefully ineffective. Very little is actually known concerning the agents involved, and as yet no method seems to have been devised whereby they may be more thoroughly investigated in the laboratory while exercising or capable of exercising such powers of cellulose dissolution as they may possess in the natural habitat. The inevitable result of the artificial laboratory methods was inactivity and inefficiency on the part of the cellulose-destroying micro-organisms.

By studying the elemental needs of the cellulose-destroyer, aided by suggestions from nature, it should be possible to obtain, under controlled conditions, an artificial fermentation of cellulose of maximum efficiency, even surpassing that commonly observed in nature.

The most important factors concerned in the artificial fermentation of cellulose of maximum efficiency, seem to consist of the following:

a) The forms of cellulose employed.
b) The nitrogenous constituent of the culture medium.
c) The provision of essential food or stimulating factors.
d) The associative action of micro-organisms.

In previous papers (Sanborn 1926, 1927) the author has shown that the growth and physiological efficiency of cellulose-destroyers are markedly influenced by the presence of a so-called essential food factor in the medium and by microbial associations. The present article deals with the preparation and use of a new medium for the physiological investigation of cellulose fermentation.

EXPERIMENTAL

Based upon the physiological proclivities of the cellulose-decomposing organisms studied and the successful application of the H-ion technique as a criterion of the rate of decomposition, a medium has been developed which furnishes a convenient method of testing the influence of stimulative factors upon the physiological efficiency of cellulose-destroyers. In the previous work it was found desirable to employ a natural, unaltered form of cellulose. Raw cotton, which was selected, proved highly satisfactory. The seed fiber of the

milkweed is yielding favorable results, particularly in microscopic methods of studying cellulose dissolution. Filter paper, in general, proved to be relatively resistant to attack.

A nutrient solution of the following composition served the purposes of the experiment satisfactorily.

K_2 HPO_4 —1 gm.
Mg SO_4 —1 gm.
Na_2 CO_3 —1 gm.
$(NH_4)_2$ SO_4 —1 gm.
H_2O (dist.) 1000 c. c.

The utilization of nitrogen compounds by micro-organisms has been the subject of some detailed consideration of recent years, (Moore 1924, Brown 1925). One of the phenomena reported by numerous workers using ammonium salts, is the unequal utilization of the basic and acidic radicles by micro-organisms, resulting in the accumulation and liberation of radicles to varying degrees. Various sources of nitrogen were employed by the author, excluding, however, organic forms. An effort was made to produce a medium containing as ammonium salt which, when inoculated, would not undergo a change in reaction inimical to the detection of cellulose fermentation by the China blue-aurin reaction.

The composition of the liquid medium is as follows:

Basic nutrient solution	500 c. c.
Precipitated raw cotton	500 c. c.
China blue-aurin solution	10 c. c.

The indicator is obtained by mixing equal parts of 0.5 per cent aqueous solution of China blue with 1.0 per cent solution of rosolic acid in 95 per cent alcohol. The raw cotton was precipitated according to the method of McBeth, (McBeth 1916). The cellulose was dissolved as rapidly as possible with constant shaking, and precipitation followed immediately.

This medium may be introduced into large culture tubes and autoclaved. The solution in this form is effective for the study of cellulose fermentation is soils. To prepare the solid medium, 1-5 per cen agar is dissolved in the nutrient solution. The cotton is added, and then, with constant strirring, the indicator. The medium becomes of a bright red color which is not affected by the autoclaving which follows. The Ph of the completed medium is approximately 8.0.

The China blue-aurin-cellulose medium is an important feature of a soil investigation in progress at this laboratory, Through its use information may be secured relative to the prevalence and physiological efficiency of cellulose-

destroyers in soil, and the isolation of these organisms will be considerably facilitated. Numerous species of bacteria and filamentous fungi have been isolated according to this method. In twenty-four to forty-eight hours a clear blue zone appeared about the growth, the blue extending well into the red medium. The clear zone was usually fairly definite. In the case of the filamentous fungi investigated, the plate frequently cleared completely within three weeks.

Further experiments are in progress at this laboratory using these media in the investigation of various processes of natural cellulose fermentation.

Sanborn, J. R. 1926 Jour, Bacteriol. 12; 1.
Sanborn, J. R. 1926 Jour. Bacteriol, 12; 343.
Sanborn, J. R. 1927 Jour. Bacteriol, 13; 113.
Moore, E. S. 1924 Ann. Bot. 38; 137.
Brown, W. 1925 Ann. Bot. 39; 373.
McBeth, I. G. 1916 Soil Sci. 1; 437.

CORN IMPROVEMENT BY SELECTION IN SELF-FERTILIZED LINES

By L. C. Raymond, M. Sc., MacDonald College

Introductory:—

Corn breeding methods have undergone a very considerable change in the past ten or fifteen years. The change has been essentially, one of shifting from mass selection to self-fertilization, with progeny selection, followed by recombination of the most promising lines developed. The former method was one of limited possibilities and most of these were exhausted. The newer method has a much wider scope and moreover is founded on a sound genetic basis.

This method of selection in self-fertilized lines is not confined to corn but is now employed extensively in all the naturally cross-fertilized crops. The corn crop, however, is a particularly easy one to manipulate owing to its monoecious habit and since the plant itself is of a very convenient stature and has its seed neatly arranged in a large and readily studied unit—the ear.

Methods employed:—

The Agronomy Department started breeding work in corn by the selfed-line method in 1922. One hundred ears of the North Western Dent variety, from a previously mass selected stock, formed the foundation material. These ears were selected for uniformity in all regards and were strikingly similar in appearance. One row was planted in the field from each one of these ears. When tassels and ear shoots began to appear self-fertilizing was begun and in each row five to ten plants, chosen at random, were selfed.

The following spring, from the selfed ears in each line, two or three ears were chosen to plant an ear-row. No attempt was made to select ears of any definite type—maturity or ability to germinate was the only criterion. Before selfing in the summer, however, the two or three sister rows were carefully examined and usually only the one which was best was retained. The basis for this choice was the degree of freedom from undesirable characteristics, whether morphological or pathological. This is one of the distinct departures from the old mass selection system. Formerly great stress was laid on the individual excellence of the ear where now the emphasis is placed almost entirely on the progeny.

The general scheme followed is the same in subsequent years. Each year as many ear rows were planted, from each line retained, as space would permit. Only the best rows in any one line and only the best lines were harvested. This is the stage where, obviously, intelligent selection may be practised. The material that we are planting this year (1928) has been selfed six times.

The effects of selfing:—

Probably the most immediate effect of selfing is to be found in reduced stature. The effect of one years selfing is to reduce the average height by about one third. Continued selfing still further diminishes height and, in many cases vigor, until after three or four generations there is little, if any, more reduction. But this is not by any means a uniform occurrence—some lines are reduced comparatively little while others become almost dwarf.

When one has an opportunity to examine the material closely, from year to year, the effect of selfing on stature is not so conspicuous as many other things that occur. There is an immediate and diverse segregation within all lines resulting in the production of plants and ears of almost every conceivable description. Some of these are strong, clean and desirable sorts, others through deficiences of one sort and another are entirely worthless and all stages in between are represented. Time will only permit discussion of a few of the undesirable types that occur.

One of the most common segregates throughout these selfed lines has been some form of chlorophyll deficiency. White and yellow seedlings were conspicuous in the early years and while no accurate counts were made they appeared in any one progeny, in approximately a three to one ratio. These are, of course lethal types and are quickly eliminated. A number of progenies have developed the so called japonica. This is a recessive to the normal green and apparently does not greatly weaken the progeny.

The type of ear, its size and the manner in which it is borne are characteristics which present very decided differences in the resulting lines. Some lines develop a single well formed ear, others uniformly two on every stalk, while others again produce a jumble of worthless ears from a single ear bud. Several

lines have borne ears within six inches of the ground while many are three and four feet high.

Marked differences are also displayed in strength. This is gererally the result of either poor root development or a weak stalk, usually the former. A heavy wind and rain storm in August reveals a great difference between progenies in this respect.

With such great differences in strength and vigor of growth as have been noted, it is but natural to expect segregation in the matter of resistance or susceptability to pathological conditions. These have been very evident since the inception of this work. Smut has been quite prevalent and the ability of the various lines, to resist attack, has been very different. Many of the better ones have never shown any smut while one in particular has developped anywhere from seventy-five percent to one hundred percent infection in the past two years. Similarly some lines rust badly, others slightly and many not at all. Many lines have developped a type of leaf spotting but whether it is a pathological or a physiological characteristic has not yet been determined. The inheritance of these and many other characters has not yet been worked out but a start is being made in that direction this year.

Some mention should also be made of the ears that have emerged from this process. As previously noted the parent ears were of uniform type and color. In the offspring the range in color alone is from self red to self yellow and white with a great variety of red, yellow and white combinations. Other kernel characters show an equally wide range.

These constitute some of the many diverse types of segregates that develop when any variety of corn is selfed. Each year the plants chosen for selfing, within any one line, represent the most desirable ones in the row. After four or five years of selfing there is little choice left as all the plants, in any one progeny, display a remarkable uniformity in every respect. This heralds the approach to homozygosity. The problem of the breeder is to select continuously both within and between the different progenies to obtain lines which combine the maximum of desirable characteristics. Of the orginal one hundred lines, over one-half have been discarded as worthless and many others will follow shortly. If five or ten good ones ultimately emerge it will be all that can be expected.

Recombination and the Result:—

Once the strains have been reduced to virtual homozygosity the most promising strains are intercrossed. The F_1 hybrid shows an immediate return of vigor expressed in stature and general vegetative development. Our work has only progressed far enough to test some of these F_1's in a preliminary way but some of them give very great promise, being taller and more productive than the original parental material. There is no basis at present to determine which two lines will react best when crossed. They must be tried out to determine this.

A similar line of work is now being done with flint corn varieties. The first F_1 hybrids between selected selfed lines of these were made last year. Combinaations of F_1 flint and dent hybrids—the so-called double crosses—have elsewhere given still greater increases in vigor and productiveness and represent one of the gaols of this type of corn breeding.

In conclusion I should like to point out the tremendous opportunities there are for recombinations in selfed line material. This same type of work is being done extensively in most of the corn growing States. Most of these have now a group of superior selfed lines of one variety or another. By interchanging this material between breeders the possible recombinations are practically unlimited. Several of the important corn States have initiated an interchange policy this year and we have been fortunate enough to make arrangements to exchange some of our best lines with Minnesota where they have been working on the same variety.

INSECTS INJURIOUS TO FOREST AND SHADE TREES AND TO FRUIT TREES AND BUSHES.

Jos. Beaulne

Buprestidae.

The family Buprestidae forms, with the Elateridae, the coleopterous group Serricornia of Latreille. This family with the Cerambycidae, Scolytidae, Curculionidae and Chrysomelidae are among the worst enemies of our forests.

The buprestids love warmth and sunshine; they are found on the trunks of trees and on the foliage and flowers of umbellifers on the pollen of which they feed. When approached they take flight if the day is fine and warm or they fall to the ground in a "death-feint".

The larvae may be recognised by the enlargment of the thoracic segments which gives them a club-shaped appearance. They are blind and legless. The larger species are destructive, feeding beneath the bark or in the wood of trees, which are already weakened from some other cause.

The majority of the buprestids are very injurious in our orchards and forests. Their tunnels are long and narrow not greatly exceeding the width of the larva. The large buprestids are the first to attack trees which have become injured by the sun, by forest fires, or by any other cause which weakens them or reduces their vitality. They are thus intermediate between those Coleoptera which feed on healthy trees such as the Cerambycidae and Scolytidae, and those like certain species of Elateridae and Lucanidae which feed on wood and bark which are already in an advanced state of decay.

The larvae of the smaller buprestids, especially those of the genus *Agrilus*, have a very flat thorax. They live in the trunks of shrubs and small trees, such

as raspberries, mulberry, willow, etc. Others, smaller still, live in leaves and herbaceous stems, (*Brachys, Pachyscelus, Taphrocerys, Acinaeodera.*)

Following is a partial list of species known to be injurious in Canada.

1—*Chrysophana* Lec.

C. placida Lec.
On *Pinus sp., Tsuga sp., Pseudotsuga sp. Abies, Thuya.*

2.—*Acinaeodera* Esch.

A. pulchella Hbst.—
On *Ceanolithus, Asclepias, Rudbeckia, Taxodium.*
A. tibilus Fabr.
On Hicoria sp., Quercus alba.
A. culta Web.—
On Geranium, blackberry and raspberry.

3.—*Chalcophora* Solier.

C. virginiensis Drury.—
On Pinus strobus, P. resinosus, P. rigida.
C. liberta Germ.—
On Pinus strobus, P. rigida.
C. fortis Lec.—
On Pinus strobus, P. resinosus.

4.—*Chalcophorella* Kerr.

C. tempestris Say.—
On Fagus americana, Salix nigra, Platanus occidentalis, Liriodendron tulipifera, Quercus sp., Fibia sp.

5.—*Trachykele* Mars.

T. blandeli Mars.
On Juniperus occidentalis, Thuya plicata, Cupressus macrocarpa, C. meanabiana, C. sargentii, Libocedrus decurrens.
T. minbosa Fall.—
On Tsuga mertensiana, Abies concolor, A. magnifica.

6.—*Dicerca* Esch.

D. divaricata Say.—
On Betula lenta, Ostrya virginiana, Tilia americana, Fraxinus americanus, Acer saccharum Cercis canadensis, Fraxinus nigra, Ulmus americanus, Pinus strobus, Fagus grandifolia, Salix alba, Prunus serotina, Pyrus sp.
D. caudata Lec.—
On Salix alba, Betula nigra, Alnus nicana, Pinus scopulorum.
D. prolongata Lec.—
On Populus grandidentata, P. tremuloides, P. trichocarpa, Salix alba.
D. sexualis Cr.—
On Pseudotsuga taxifolia, Pinus ponderosa, P. attenata.
D. pugionata Germ.—
On Hammamelis virginiana, Alnus vulgaris, Acer saccharum, Quercus alba, Spiraea sp.
D. punctulata Schan.—
On pinus rigida, P. strobus, P. ledea, P. echinata.
D. obscura Fabr.—
On Drosphyros virginiana, Rhys typhina, Quercus alba, Fraxinus oregona, Hicoria sp. Acer sp.
D. lurida Fabr.—
On Carpinus caroliniana, Alnus rugosa, Carya amara, Hicoria sp.
D. spreta Gory.—
On Nyssa sylvatica.
D. tenebrosa Kby.—
On pinus strobus, P. ponderosa, P. contorta, Abies concolor, Pseudotsuga taxifolia, Acer saccharum, Thuya occidentalis.
D. tuberculata Cast.—
On Tsuga canadensis, Abies balsamea.
D. chrysea Melsh. —
On Abies balsamea.

7.—*Poecilonota* Esch.

P. cyanipes Say.
On Populus grandidentata, P. deltoides, P. tremuloides, P. trichocarpa..
P. thureura Say.—
On Populus trichocarpa.

8.—*Cinyra* Cast. and Gory.

C. gracilipes Melsh.—
On Quercus macrocarpa, Q. alba, Q. bicolor, Ostrya virginiana, Fraxinus americana.

9.—*Buprestis* Linn.

The specis of this genus are the most harmful of all the buprestids found in Canada.
B. sulcicollis Lec.—
On Pinus strobus, P. resdinosus, P. banksiana.
B. aurulenta Lunn.—
On Pinus radiata, P. Jeffreyi, P. murryana, P. monticola, P. ponderosa, P. ponderosa scopulorum, P. saliana, Picea parrayuna, P. silchensis, Pseudotsuga taxifolia, Thuya plicata, Pinus rigida, P. contorta, Pinus lambertiana.
B. adjesta Lec.—
On Pinus ponderosa, P. myrrayana, P. jeffreyi.
B. striata Fabr.—
On Pinus strobus, P. rigida, P. taeda, P. palustris, Tsuga canadensis.
B. striata var *impedita* Say.—
On Pinus strobus, P. rigida.
B. lineata Fabr.—
On Pinus virginiana, P. strobus, P. taeda, P. palustris, P. rigida.
B. maculipennis Gory.—
On Pinus rigida.
B. subornata Lec.—
On Pinus ponderosa, Pseudotsuga taxifolia.
B. maculiventris Say.—
On Pinus strobus, P. resinosus, P. banksiana, P. ponderosa scopulorum, Abies balsamea Tsuga canadensis.
B. maculiventris var *rusticorum* Kby.—
On Pinus ponderosus, Pseudotsuga taxifolia, Abies grandis, Abies lasiocarpa, A. concolor.
B. nuttalli Kby.
On Pinus ponderosa scopulorum.
B. nuttalli var *consularis* Gory.—
On Pinus rigida, P. virginiana, P. ponderosa scopulorum, Pseudotsuga taxifolia, Abies balsamea.
B. laeventris Lec.—
On Pinus ponderosa, P. murrayana, P. contorta, P. rigida, P. lambertiana, P. radiata, P. sabiniana.
B. rufipes Oliv.—
On Pinus taeda, Castanea dentata, Quercus alba, Q. virginiana, Liriodendron tulipifera, Ulmus americana, Nyssa sylvatica, Fagus grandifolia, Acer saccharum, Carya ovata.
B. confluenta Say.—
On Populus tremuloides, P. deltoides.
B. fasciata Fabr.—
On Pinus strobus, Populus tremuloides, Salix nigra, Acer saccharum.
B. fasciata var. *langi* Mann.—
On Pinus ponderosa, Populus tremuloides, Salix nigra, Pseudotsuga taxifolia, Abies grandis.
B. gibbsi Lec.—
On Quercus californica, Populus trichocarpa.

10.—*Melanophila* Esch.

M. gentilis Lec.—
On Pinus lambertiana, P. ponderosa scopulorum, P. jeffreyi.
M. intrusa Horn.—
On P. lambertiana, P. ponderosa scopulorum, P. ponderosa.
M. drummondi Kby.—
On Abies nobilis, A. magnifica, A. lasiocarpa, A. grandis, A. concolor, A. amabilis, Larix occidentalis, Picea engelmanni, Picea sitchensis, Pinus ponderosa, Tsuga mertensiana, T. heterophylla, Pseudotsuga taxifolia.

11.—*Anthaxia* Esch.

A. viridifrons Gory.—
On Ulmus americana Carya amara, C. alba.
A. aeneogaster Cast.—
On Pinus, lambertiana, P. edulis, P. ponderosa, P. jeffreyi, P. sabiana, P. attenata, P. radiata, Pseudotsuga taxifolia, Salix babylonica, Quercus garryana, Amelanchier almifolia, Cercis occidentalis.
A. viridicornis Say.—
On Ulmus americana, Carya amara.
A. quercata Fabr.—
On Cercis canadensis, Crataegus occcinea, Pinus strobus, Castanea dentata, Quercus alba.

12.—*Chrysobothris* Esch.

This genus of buprestids causes a great deal of damage among ornamental trees, fruit tress etc., whether in nurseries, permanent plantations or in the woods. The large commercial orchards of apples, plums, peaches, pears, apricots, cherry, quince, are often practically ruined by insects of this genus, the larvae of which live in the twigs, branches, trunks, or roots of the young plants. They are usually to be found beneath the bark where they make sinuous tunnels which become filled, behind the insect, with a whitish fras and rust-brown excrement. At the approach of winter they bore into the wood. When they are about to pupate they again make their way towards the surface. The adults emerge in June, July or August and may be found on the trunks and branches of trees which have been recently cut down or injured in some way. They are sun-loving insects.
C. chrysoela Ill.—
On Diospyros sp., Hammamelis virginiana.
C. sexsignata Say.—
On Tsuga canadensis, Fraxinus nigra, F. americanus, Quercus bicolor, Juglans nigra, J.cinerea, Acer rubrum.
C. lecontei Leng.—
On Quercus bicolor, Alnus vulgaris.
C. mali Horn.—
On Salix lasiolepis, Pyrus malus, Heleromeles arbutifolia, Prunus domestica, P. subcordata, P. persica, Acer macrophyllum, A. negundo.
C. pusilla Cast.—
On Pinus rigida, P. palustris.
C. trinervia Kby.—
On Pinus strobus.
C. verdigripennis Frost.—
On fagus grandifolia, Tsuga canadensis.
C. dentipes Germ.—
On Pinus strobus, Quercus rubrum.
C. floricola Gory.—
On Pinus strobus, P. palustris.
C. femorata Oliv.—
On Populus tremuloides, P. nigraitalica, Quercus gambeli, Q. chrysolepis, Q. californica, Populus trichocarpa, Carya amata, Acer saccharum, A. dasycarpum, Prunus americana, P. domestica, P. pennsylvanica, P. cerasus, Quercus alba, Tilia americana, Fagus americana, Pyrus sp.
C. scabripennis Cast.—
On Pinus strobus.
C. harrisi Hentz.—
On Pinus virginiana, P. strobus, Alnus incana.
C. blanchardi Horn.—
On Pinus strobus.

13.—*Actenodes* Lac.

A. acornis Say.—
On Acer rubrum, Fagus americana, Betula nigra, B. lenta, Carya amara, Quercus velutinus.

14.—*Eupristocerus* Deyr.

E. cogitans Web.—
On Alnus vulgaris, A. rugosa, A. incana.

15.—*Agrilus* Steph.

The larvae of this genus often form galls sufficiently injurious to check the growth of the plant especially on raspberries and black-berries.

A. frosti Knull.—
On Quercus alba.
A. bilineatus Web.—
On Quercus alba, Fagus americana, Castanea dentata, .
A. acutipennis Mann.—
On Quercus rubrum, Q. gambelis, Carylus americana.
A. anxius Gory.—
On Populus grandidentata, P. tremuloides, P. deltoides, Betula frontinalis, B. argentata, Salix sp.
A. lacustris Lec.—
On Croton capitatum ,C. eleagnifolium.
A. pensus Horn.—
On Alnus incana.
A. ruficollis Fabr.—
Very injurious to raspberries and blackberries.
A. laterilis Say.—
On Populus deltoides, Alnus incana.
A. masculinus Horn.—
On acer negundo, Quercus rubrum.
A. egenus Gory.—
On Robinia pseudacacia, Carya amara, Cornus sp., Hicoria alba., Ampelopsis sp., Salix sp.
A. caphalicus Lec.—
On Corylus americana, Cornus florida.
A. arcuatus arcuatus Lec.—
On Quercus velutina, Fagus americana, Hicoria ovata.
A. arcuatus coryli Horn.—
On Corylus americanus, C. rostrata.
A. fallax Say.
On Gladitsia triacanthus, Quercus rubrum, Cercis canadensis, Celtis occidentalis, Pseudacacia sp.
A. subcinctus Gory.—
On Rhus toxicodendron.
A. otiosus Say.—
On Carya amara, Acer negundo, Juglans cinerea, Corylus sp., Juglans nigra, Cercis canadensis, Quercus rubrum, Gleditsia triacanthus, Acer rubrum.
A. politus Say.—
On Acer pennsylvanicum, Salix mont cola, S. lasiolepis, S. babylonica, Alnus tennifolia, Acer glabrum, Salix obtusifolia, Corylus americana, C. rostrata, Quercus sp.
A. obsoletoguttatus Gory.—
On Fagus americana, Carpinus carolininiana, Quercus rubrum, Ostrya virginiana, Carya amara, Betula nigra, Hicoria sp.
A. vittaticollis Rand.—
On Amelanchier canadensis, Crataegus coccinea, Pyrus malus, Prunus cerasus.
A. granulatus Say.—
Ou Populus trichocarpa, P. deltoides, Alnus incana, Salix vitellina.
A. lecontei Saund.—
On Celtis occidentalis.

16.—*Pachyscelus* Solier.

P. ovatus Say.—
On Lespedezia, Merbonnia, Asclepias. (Larvae mining in leaves).

17.—*Brachys* Solier.

B. aerosus Melsh.—
On Tilia americana, Carya amara, Fagus grandifolia, Ulmus americana.
B. aeruginosus Gory.—
On Fagus grandifolia, Quercus rubrum.
B. ovatus Web.—
On Quercus rubrum.

18.—*Taphrocerus* Solier.

T. gracilis Say. —
On Quercus rubrum, Caphalanthus sp.

THE CHIEF INJURIOUS INSECTS OF VEGETABLES AND ORNAMENTAL PLANTS IN THE MONTREAL DISTRICT IN 1927

By Jos. Beaulne

The Cabbage Maggot (*Hylemyia brassicae* Bouché). During last season this insect caused very considerable loss among the market gardeners on the island of Montreal and on Ile Jésus. In at least 90% of the commercial plantations the loss amounted to not less than 75% of the cababges—early, mid-season and late —and cauliflower. The warm spring weather, favourable to the emergence of the fly, was largely responsible for this very heavy infestation.

If all of the gardeners in the district would plough in the autumn in order to bury the remains of the crop the infestation might be greatly reduced the following year.

In the districts where we used mercuric chloride the results were very satisfactory. It is necessary however that this tretament be made early in the spring; indeed, in the district of Montreal it should be begun while the plants are still in the seed-beds.

The Onion Maggot (*Hylemyia antiqua* Meig.). This insect tends to discourage the growing of onions in the Montreal district. We observed during our inspection that this pest had ruined some 90% of the onion fields which had given promise of a good crop. We were too late in starting the work to carry out any experiments on control, but we observed the effects of the sodium arsenite-molasses bait in certain districts. In this connection I may state that it is advisable to use earthernware receptacles when the soil is hot. If metal receptables are used the results are likely to be negative owing to oxidation.

Onions being a very valuable crop, it is undoubtedly advisable to make a special effort to control the maggot. Deep ploughing in the autumn will destroy at least 75%.

The Carrot Rust Fly (*Psila rosae* Fabr.). This is another insect worthy of careful consideration. During 1927 we made close on 200 inspections of market gardens in the district and in every case found the carrot infested with the maggot. In the course of my work I have also inspected the shops of many vegetable sellers where it is quite usual to see carrots exposed to sale riddled with the rusty tunnels made by this maggot, a condition hardly likely to encourage the use of carrots, one of our most hygienic vegetables.

Much might be done to reduce the infestation if the gardeners would select their carrots and discard the infested ones instead of throwing them in the pits with the others as is so commonly done. Prevention costs less than the purchase of insecticides and their application.

The Celery Leaf-Hopper. For several years this insect has been the chief cause of the failure of the celery crop, but since the discovery of the beneficial results of applying nicotine dust several times during the growing season the

situation has greatly improved. Application of dust by a motor duster is much more effective than application by a hand pump. During 1927 we followed closely the control measures of M. Guinois of St. Michel and are convinced that it is practicable to grow celery profitably by controlling this pest.

The Potato Beetle (*Leptinotarsa decemlineata* Say). Since Provancher (Nat. Can. III, 87-90; VII, 173-175) noted the introduction of this insect into Quebec, a great deal, in one way or another, has been written concerning it. Last year it did very considerable damage in spite of repeated sprayings even with strenghts above those usually recommended. On investigation it was found that the Paris green used was defective. The laws should be more strictly enforced to compel the manufacturers to place a pure or standardized article on the market. This could be accomplished by empowering the inspectors to take samples from the factories or retailers from time to time for analysis. This method is widely practiced in the United States.

The Cabbage Worm (*Pontia rapae* Linn.)—This caterpillar was quite plentiful in 1927. Fields of late cabbage suffered heavily. The parasites which usually serve to keep it in check were not very numerous. In this district the gardeners make little effort to control the caterpillar allthough there is a considerable amount of information available on the subject. For us in Quebec this information goes back to the time of Provancher. (Can. Nat. II, 13-18, V. 125-127). Since this time the Department of Agriculture of Quebec has done a great deal to help the gardener to control the pest. The same may be said of the Quebec Society for the Protection of Plants.

Dusting with 1 lb. lead arsenate to 10 lbs. of flour has given good results.

Having mentioned the principal pests affecting market-garden crops during the season I shall say a few words regarding the chief green-house pests encountered.

The Cyclamen Mite (*Tarsonemus pallidus* Banks).—These extremely small, glassy mites may be quite injurious to potted cyclamens. They feed on the foliage and leaves which at first turn violet in colour then reddish, and finally die and fall off. The mite was found in all greenhouses in the Montreal district in which cyclamens are grown commercially.

Snap-dragon, geranium, begonia, fuhscia and chrysanthemum are also attacked.

Dusting with nicotine sulphate is recommended as a means of control. If the injury is very severe the infested plants should be burnt.

The Chrysanthemum Thrips (*Heliothrips haemorrhoidalis* Bouché).
In a green-house at Côte des Neiges this insect almost completely destroyed 27,000 chrysanthemum plants. It was the first attempt of the florist to grow chrysanthemums on such a large scale and our attention was not drawn to the infestation until it had become quite severe. The nicotine sulphate dust was

found to give satisfaction and if the treatment had begun two or three weeks earlier the situation might have been saved.

The thrips may also be controlled by fumigating with hydrocyanic gas or with nicotine.

Other ornamental plants such as crotons and cyclamens are also attacked.

Pill-bugs or Woodlice.—These are not true insects but belong to the group of animals known as the isopod crustaceans. In the grenhouse they cause considerable injury by eating at night the leaves of the following plants, ferns, carnations, sweet-peas, begonia, coleus, primula, geranium and cineraria.

Bits of potato or carrots which have been hollowed out make good traps. A poison bait made of a mixture of 1 part Paris green and 10 parts icing sugar, scattered along the beds, has been found to give good results. Above all care should be taken to keep the greenhouse clean and to eliminate any adventitious material under which the pillbugs may collect.

Slugs.—Several species of slugs have given trouble to the florists in the Montreal district. Like the pill-bugs they do their damage at night. A very good method of control is to broadscast lime over the soil where the slugs are troublesome.

Slugs feed greedily on the foliage of chrysanthemum, marigold, snapdragon. cineraria, coleus, geraniums, sweet-peas, and especially hot-house tomatoes,

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PLANT DISEASES OF LOWER QUEBEC DURING 1927 (1)

By Elzear Campagna, Agricultural College, Ste. Anne de la Pocatière.

This note is an attempt to bring to the attention of the members of the Quebec Society for the Protection of Plants the principal vegetable parasites encountered in several counties below Quebec (2) during the months of July, August and September 1927. The excuse, if any is needed, for presenting these notes of secondary interest lies in the incompleteness of our knowledge of the ecological conditions of the territory, and of the fauna and flora thereof. It is important therefore that those interested in the protection of plants should have as far as possible, a complete list of the vegetable parasites of the regions, their local distribution, their hosts and their economic importance.

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(1) These investigations were made partly in collaboration with Mr. Omer Caron, Botanist to the Department of Agriculture, Quebec. I would acknowledge the courtesy of the Deputy Minister of Agriculture for Quebec, and of Mr. Georges Maheux, Entomologist to the Department of Agriculture.

(2) Counties of Rimouski, Temiscouata, Kamouraska, L'Islet, Montmagny, Bellechasse and Levis.

Having made this preliminary survey we are then in a position to study the etiology of those organisms of economic importance and to use the experience gained in other regions in devising means for their control.

I do not wish the members of the Society, however, to get the impression that nothing is being done in pest control in this region; on the contrary the divisions of Entomology and of Botany at Quebec, the Dominion Laboratory of Plant Pathology and the School of Agriculture at Ste Anne have done and are doing a great deal to assist the farmer in controlling insect pests and plant diseases. To speak more particularly of the School of Agriculture, because I am best aquainted with its activities, I might say that since 1920 it has distributed annually in collaboration with the agronomes or directly, 300 to 400 pounds of formalin to the farmers of Kamouraska and L'Islet.

Of the diseases observed during last summer we have limited ourselves in this report to those which may be of economic importance. The localities in which they are most abundant are mentioned, and they are classified arbitrarily according to their hosts.

DISEASES OF CEREALS

Wheat:—

Naked Smut (*Ustilago tritici* (Pers.) Jens.) Found in all fields visited except two. The infection was not severe, not exceeding 1.5% the average fields showing traces to 1%.

Black Stem Rust (*Puccinia Graminis* (Pers) Found in all fields visited but particularly severe iu humid areas where the infection varied from 30% to 65%.

Leaf Rust, caused probably by *Puccinia triticina* Eriks. Infection abundant but not severe. The affected plants were not noticeably injured.

Ergot of Rye (*Claviceps purpurea* (Fr.) Tul.) Four heads of wheat with ergot well developed were found by Mr. G. Lagace at Ste Anne. This is the first time we have seen ergot on wheat in Kamouraska. In La Gaspesie we understand that Mr. Moise Gagnon has seen fields of wheat noticeably affected with this disease.

Stevens in his treatise on "Plant Disease Fungi" gives rye wheat and oats as the hosts of ergot. Until now, at least in our district we have seen ergot only on rye and other forage grasses.

Oats:—

Naked Smut (*Ustilago avenae* (Pers) Jens. With regard to the number of fields visited oats take the first place. In the localities under consideration smuts have not sensibly affected the cultivation of oats this year. The most heavily infected fields encounted did not contain more then 3.5% of naked smut. The average was less than 1%.

If we compare these figures with those which we ourselves compiled in 1923 we find a considerable decrease in the incidence of smut which we attribute to the following causes.

1. The excellent work of the department of Agriculture and similar institutions in introducing the use of formalin among the farmers.

2. An important natural factor seems to come into play, to explain which it is necessary to say a few words regarding the life cycle of the parasite. The spore on germinating penetrates into the young plant. Within the stem the mycelium develops as the plant develops. When the head begins to form there is present an excess of the principal food of the parasite. In utilizing this excess of food the fungus produces its spores.

According to Neveu-Lemaire there will be more smut during a dry summer, because "si par un printemps très sec la croissance de la céréale est ralentie, le parasite prend le dessus et le charbon se développe. Si, au contraire, le céréale croit rapidement, le mucelium n'atteint pas le sommet de la tige en croissance et la plante reste indemne".

Last summer we had dry weather in the early part of the season followed by rains sufficiently abundant to bring about a rapid growth of the grain. As a result the growth of the stem exceeded that of the mycelium so that spores did not develop and the amount of smut was thus greatly decreased.

Black Stem Rust. (*Puccinia graminis* Pers.) Found in nearly all of the fields inspected. The infection varied from 5% to 85%. The coming on of the dry weather in July retarded the development of the rust and the oats have not suffered very much.

Barley:—

Naked Smut and Covered Smut of Barley. (*Ustilago nuda* (Jens). K. & S. et *Ustilago hordei* (Pers.) K. & S.) There were no large areas sown to barley but only small fields of one or two acres. The smutted heads were more numerous than in the case of oats, varying from 0.5% to 2.5%.

Black Stem Rust. (*Puccinia graminis* Pers.) Infection as in the case of oats.

DISEASES OF FORAGE CROPS.

Clover:—

We did not examine any fields of clover without finding one or more of the following diseases: *Powdery Mildew* (*Erysiphe polygoni D. C., Clover Rust* (*Uromyces trifolii* (Hedw.) Lev.) *Leaf Spot* (*Pseudopeziza trifolii* Fckl.)

What is the importance of these diseases in the culture of leguminous forage crops?

The farmer who cuts his leguminous crop early, as soon as they are in flower, suffers little loss, at least in our country where these diseases seem to develop less rapidly than in the warmer climate of the United States. On the other hand, if the crop is left until half the seed has almost matured, most of the diseased leaves will have fallen to the ground or will fall as soon as the plant is cut. Thus the crop is reduced fron 50% to 75%, if not in volume at least in quality.

We have given special attention to clover grown for seed and have always found one or other of these diseases, especially the rust. In some areas the defoliation was complete to the middle of the stem while the remaining leaves at the top of the stem were all diseased. We were therefore not surprised to find that in these areas the clover crop was mediocre.

Alfalfa.—

In an old alfalfa field on the farm of the school of agriculture at Ste-Anne de la Pocatiere we found a quite severe infection of alfalfa leaf-spot (*Pseudope peziza medicaginis* Lib.) Sacc.).

Vetch:—

Vetch Rust. (*Uromyces sp.*) Very little on cultivated vetch, but abundant on the wild vetch especially on the clayey lands bordering the Ouelle River.

DISEASES OF FRUIT TREES.

Apple:—

Apple Scab (*Venturia inequalis* (Cke.) Wint.). Epidemic in certain orchards in Ste Anne, Rimouski, St-Pascal, Montmagny.

Cherry and Plum:—

Black Knot (*Dibotryon morbosum* (Sch.) Theiss and Sydow). Riviere Ouelle, Ste-Euphemie, St-Andre.

Plum:—

Shot-hole Disease (*Coccomyces sp.*) Rimouski.

Apple:—

Fire-blight (*Bacillus amylovorus* (Burr.) Trev. This disease is as grave a menace to our orchards as the European cornborer is to our corn crop, and deserves the same attention as the gypsy moth. It is fully established in Lower Quebec. Last summer we fund it in Montmagny County and shall not be surprised to find it in other regions next year. H. N. Racicot reports it in Kamouraska County (Drayton: Survey of the prevalence of plant diseases in the Dominion of Canada: 59, 1923). In the same report it is mentioned as occurring in Matane and L'Islet. Immediate steps should be taken to combat this disease or we may be subjected to the losses caused by this pest in parts of New York State and elsewhere.

Gooseberry:—

Powdery Mildew (*Sphaerotheca mors-uvae* (Schw.) B. & C. This disease was found readily in all the regions visited and was causing quite considerable loss. One gardener at Rimouski claims to have lost about 250 dollars last year

from the mildew. More than half of his mature berries were covered with mildew and not marketable. In other regions from 10% to 25% of the fruit only was clean and fit for consumption. As a rule the farmers make little attempt to control mildew. They think that their bushes are sickly and that the black coating on the fruit is due to the oozing out of the sap. It is difficult to control mildew completely but by paying attention to cultural methods, by removing the dead leaves which fall in the autumn, and by keeping the soil around the bushes well drained, much might be done to reduce the loss. Where gooseberries are grown commercially a spray of sulphate of potassium (1 to 1½ ounces in two gallons of water) should be applied at the time the buds open and repeated two or three times at intervals of twelve or fifteen days.

Plum:—

Plum pockets (*Taphrina pruni* (Fel.) Tul.). Rosaire, Ste-Euphemie, St-Paul du Buton, Ste-Louise (mentioned particularly by M. Omer Caron).

Currant:—

White Pine Blister Rust (*Cronartium ribicola* (Froch von Wald). Ste. Anne, St. Roch, Rimouski, Notre Dame du Lac.

Strawberry:—

Leaf-spot (*Mycosphaerella fragariae* (Schw.) Lind). Found chiefly on the wild strawberry in all the counties visited.

ORNAMENTAL PLANTS

Roses:—

Rose rust (*Phragmidium sp.*). This disease was found in many localities and may be regarded as being epidemic throughout large areas of Lower Quebec. The disease varies in severity. It is present on both wild and cultivated roses. On the latter it often causes a premature defoliation (about the middle of August) which prevents the development of the young shoots, impairs the general vigour of the plants, and greatly reduces the number of blooms.

FOREST TREES

White Spruce and Balsam Fir:—

Witches' Broom or Dwarf Mistletoe, caused by the phanerogamic parasite *Arceuthobium pusillum* (Peck) was found in several areas in Kamouraska (Ste Anne, Montagne du College, Cap-Martin, Montagne Thiboutot, on the heights of St-Onesime, in the park of St. Denis, on the heights of St. Denis, Pointe aux Marsouin, etc).

Up to the present we have found *Arceuthobium* on *Picea Canadensis* and *Abies Balsamea*. According to Gray's Manual of Botany, seventh edition the parasite is found on plants of the genera *Picea* and *Larix*.

Brother Marie-Victorin in his recent memoir on the Gymnosperms of Quebec gives the following interesting statement on this parasite: "White spruce, black spruce, balsam fir, and sometimes even the larch are parasitized by one of the lowest and most curious Phanerogams of our flora, *Arceuthobium pusillum*, our only mistletoe, and sole representative of the large tropical family, the Loranthaceae. This parasite grows on the branches and pierces the bark and wood of its host with its suckers. In the space of an inch as many as fifteen individuals may be found, The host reacts in the ordinary way by producing new tissues. If the seed of the parasite germinates on a branch which is weak and already half killed by the surrounding shade the affected branch will become elongated and its foliage will become discoloured. If on the other hand the affected branch is strong and vigorous, after a number of years there is produced "a witche's broom" resembling those formed by the various species of *Peridermium*. These deformities increase on the tree, gradually weakening it and eventually causing its death. The fruit which is pestle-shaped is viscous and strongly hygrometric. In the autumn, on a damp day, the seeds of the parasite are forcibly ejected and rapidly infect neighbouring trees" Where it is found this parasite is very destructive to forests.

At Ste Anne we have not been able to discover any injury in the forests, but on the north slope of the Montagne du College a stand of *Picea Canadensis* has been partly ruined and is menaced with destruction, *Arceuthobium pusillum* aided by certain species of *Fomes* seems to be the cause of the injury. (1)

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(1). In this paper I have included much of the matter which is to be found in the general report which I have made for Mr. Georges Maheux, Provincial Entomologist.

THE ONION ROOT-MAGGOT (HYLEMYIA ANTIQUA MEIG.) ON THE ISLAND OF MONTREAL. (1)

By Alex. D. Baker M. Sc. and K. E. Stewart M. Sc., Department of Entomology, Macdonald College, McGill University.

1.—INTRODUCTION.

The work covered by this report was done during the summers of 1924-1927 at Macdonald College, Que., and various onion fields in the vicinity of Rosemount, Montreal, chiefly those on the farm of Mr. J. J. McEvoy.

Many tables and charts, etc., have been omitted from this report for the sake of brevity, particularly where the results were largely negative in character.

It will be noted that certain aspects of the work have been given more attention than others and that the bionomics of the insect has been stressed somewhat. Our aim was to duplicate as little as possible such work as had already been performed by other workers and to emphasize the study of the problem from newer angles, where any promise of success seemed possible. Necessarily this entailed a considerable amount of preliminary experimental work and observation; to be followed later by more extended efforts along fewer lines. The summer of 1924 was largely taken up with this preliminary work. The results obtained were such that the financial support of the National Research Council was sought and obtained, with the result that it was possible to extend the work in subsequent years and also secure the services of Mr. K. E. Stewart during the season of 1925.

We feel that, in many cases, appreciable light has been thrown on certain points of the problem that had not previously been touched upon, as well as considerable confirmatory data having been secured. We trust that our findings may have some influence in bringing one of the most important pests of truck garden crops under control.

We are pleased to acknowledge laboratory assistance received from Mr. E. Bynce and Mr. F. Olmsted during the summers of 1925 and 1926 respectively.

2.—HISTORICAL REVIEW.

The onion maggot has been known in Europe for many years. It is to be found in Britain, Austria, Russia, Czecho-Slavokia, Italy, Sweden, Germany, Holland and Switzerland.

(1) A grant in aid of this investigation was received from the National Research Council of Canada. The grant was administered and the work directed by Professor E. Melville DuPorte.

In Great Britain the maggot has been known for a long time, it having been reported as doing considerable damage at Dorking, England (1.) in 1840. It now occurs in all the onion growing districts of England, Scotland and Wales. Smith, K. M. (29) in 1922. states, "*Hylemyia antiqua* has become so abundant of recent years in Great Britain, and particularly in Lancashire and Cheshire, that in certain districts onion growing is impossible."

The onion maggot was imported into North America from Northern Europe and the first records of it as a serious pest came from the states of Massachusetts and New York. It is thought to have been brought over in shipments of onion bulbs from Sweden, Holland, Denmark and England. It was first noted by T. W. Harris (2) in a report of injurious insects of Massachusetts. Again in 1862 Harris (3) calls attention to the destructiveness of this insect. Other early reports were made by Fitch (4) 1866, Lintner (7) 1882, Fernald (10) 1891, Smith (12) 1893, Slingerland (13) 1894; and many others.

In recent years it has become widely distributed and is now found in the following states—Pennsylvania, New Jersey, New York, Connecticut, Massachusetts, Michigan, Indiana, Wisconsin, Illinois, Minnesota, Iowa, Montana and Oregon. It does not, however, generally occur south of the State of New Jersey (21).

The first reference made to the onion maggot in Canada was in 1875 by Couper (5) and by this time it had become well established in Ontario and other parts of Eastern Canada. Attention was again directed to this pest by Dr. Fletcher (9) in 1885 and in 1891 (11) he stated that it was equal in destructiveness and more difficult to deal with than the cabbage and radish root maggots. Apparently the Province of Quebec did not suffer any serious losses from this insect until 1908, when Dr. Swaine (16) reported it damaging the onion plants at Macdonald College, Ste Anne de Bellevue. In 1920 many infestations occurred throughout the province and have continued up to the present time. This insectis now considered to be one of our most important pests.

Hylemyia antiqua is now prevalent in Canada from coast to coast, it having been mentioned as occurring in British Columbia in Dr. Fletcher's report (14) for 1904. During 1914 and 1915, Treherne (27) states that some growers were forced to abandon commercial onion growing in that province.

This insect was first described in Europe by Meigen in 1826. In 1833 Bouche gave an account of this species, and in 1855 Marquart included it in his "Histoire Naturelle de Diptera".

The onion maggot has been listed under various names. The following are these most frequently met with in the published accounts of this insect.

1826 *Anthomyia antiqua* Meig. Syst. Besch *r.*, Vol. 5, p. 166, No. 145.

1830 *Anthomyia ceparum* Meig. Syst. Besch *r.*, Vol. 6, p. 376, No. 217.

1844 *Musca liturariae* Ratzed. Forstins., Vol. 3, p. 170, No. 1.

1851 *Anthomyia caepicola* Rob. — Desv. Guer. — Men., Rev. et Mag. Zool., Ser. 2, Vol. 3, p. 234, No. 1.

1882–83 *Chortophila cinerea* Meade nec Fall. Ent. Mo. Mag., Vol. 19, p. 147.

1882–83 *Phorbia cepetorum* Meade. Ent. Mo. Mag., Vol. 19, p. 218.

1893 *Anthomyia angustifrons* Strobl. nec Meig. Verh. Zool. — Bot. Ges. Wein, Vol. 43, p. 259.

Bezzi and Stein in their catalogue of European Anthomyiidae, 1907, place the onion maggot under the name *Holemyia antiqua*. This name has been accepted in Europe and is now the name adopted on the American continent.

F. H. Chittenden believes that south of the state of New Jersey *Hylemyia antiqua* is largely replaced by *Pegomyia fusciceps*.

3.—ECONOMIC IMPORTANCE AND DISTRIBUTION IN QUEBEC.

Hylemyia antiqua is undoubtedly the most destructive of any insect infesting the onion plant. It is well distributed throughout the province, apparently occurring in all the districts where onions are grown to any extent. It is also often surprisingly numerous in comparatively isolated regions even where onions are being grown only in small numbers, such as in a kitchen garden, etc. The distribution of the insect would almost indicate that very active dispersal on the wing took place and that wild host plants might sometimes be necessary to carry the insect over from one onion crop to another, but at the present time we have no evidence to support either of these assumptions. As previously indicated by Armstrong the insect is most prevalent in the province of Quebec on the southern side of the St. Lawrence river, and in all regions where onions are grown through to the International boundary.

Every year the onion crop in the province of Quebec is depleted to some extent. In some years the infestations may be comparatively light but in other years very severe losses have occurred and the insect is always a constant source of worry to growers of onions, the insect is always present and they are never safe from the possibility of very severe and often almost complete loss of their onion crop.

Hammond, in the Ottawa district, records taking eggs on garlic and leek as well as the onion, but he also states that fewer larvae feeding in garlic and leek material matured. In this locality the attacks of this insect are apparently confined to the onion.

4.—OTHER INSECTS FOUND INFESTING ONIONS.

While several species of Diptera have been recorded as feeding on the onion bulb *Hylemyia antiqua* is apparently the only one that attacks a healthy onion. Onion bulbs in a semi-rotten condition, which condition may in the first instance have been due to onion root maggot attack, are often readily attacked by other insects.

Armstrong (30) records the following insects as being reared from semi-decayed onion bulbs in the province of Quebec:—

Diptera:

1. *Muscina stabulans* Fall.
2. *Muscina assimilis* Fall.
3. *Eumerus tuberculatus* Rond. (Syrphidæ).
4. A drosophilid fly.

Coleoptera:

1. *Omosita colon* Linn. (Nitidulidæ).

All of the above insects have been found on decaying onion bulbs. In no case have any of them been recorded as occurring on a healthy plant. *Eumerus tuberculatus* Rond., has been regarded as an enemy of onions in the old world, together with *E. strigatus*, but as Armstrong states: "In Canadian literature the fly has gone under the name of *strigatus*. However, according to Mr. Curran of the Systematic Division of the Entomological Branch at Ottawa, all records except one refer to *E. tuberculatus* and not *strigatus*". This insect has been recorded as quite numerous in the onion fields of this province but never as attacking an onion that had not previously been injured by *Hylemyia antiqua*. It would appear, then that the presence within the onion bulb of any of the insects noted above is purely secondary, the onion plant being attacked only when in a rotting or diseased condition, a state that frequently follows onion maggot invasion.

5.—DESCRIPTIONS OF STAGES.

The egg.

Slightly over a millimeter in length and about half as broad. They are white in color with distinct ridges, and a shallow depression running down one side of the egg for about ⅓ of their length. The general shape is oblong-oval, somewhat flattened at one end and rounded at the other.

The larva.

Dirty white in color, measuring about 10 mm. in length when full grown. A typical vermiform dipterous larva, legless, flattened at the posterior end and tapering to a point anteriorly. The posterior segment bears the posterior spiracles and a number of prominent tubercles. The number and arrangement of the latter are used to distinguish these larvae from closely allied species. At the anterior end are to be found the fan like anterior spiracles (between the 1st and 2nd segments) and the large hook-like jaws with which the maggot bores its way into the plant tissues.

The puparium.

Oval in shape, varying in length from 4-7 mm. depending on the food supply of the larva. The color ranges from light to dark brown, usually with a

reddish tinge, and the overwintering puparia are usually quite dark in color. A typical coarctate pupa but the structural characters of the larva can be made out in the puparium.

The adult.

The average body length is 6 mm. making the insect smaller than the house fly (*Musca domestica*), the latter being also darker in color than the onion fly. The female is lighter in color than the male and the eyes are widely separated. In the male the eyes are very closely set together. The onion fly is distinguished from the cabbage fly (*Phorbia brassicae*) by the absence of the conspicuous clusters of bristles which are to be found on the upper portion of the hind femora on the males of the latter.

Meade, in his Descriptive List of the British Anthomyiidae gives the following description of the onion fly:

"Head: face slightly prominent; epistome flat; eyes of male contiguous; antennae of moderate length with the arista thickened and pubescent at its base, but nearly bare in the middle and at the extremity.

Thorax: with the scutellum of a light yellowish grey colour; the former marked with four indistinct pale brown stripes, and with four rows of black bristles.

Abdomen: oblong and rather narrow, cinereous, clothed with black hairs and showing silvery white reflections when viewed from behind; it is marked down the dorsum with a row of elongated narrow triangular black spots, which form a sub-continuous stripe; the anal segment is grey, small and rather pointed; the sub-anal male appendages are large and hairy.

Wings: hyaline, with the third and fourth longitudinal veins nearly parallel to each other, and the external transverse ones straight, and a little oblique; calyptra and halteres both pale yellow.

Legs: sometimes piceous; hind femora almost bare of hairs or bristles at the base of their under sides; hind tibiae of the males furnished with a few short bristles along the middle and upper part of their inner sides. The female is very similar in colour to the male; the eyes are widely separated, the intervening space being red at its front part; the abdomen is dull grey mostly immaculate, conical and pointed at the apex; the calyptra are white and the halteres yellow".

6.—LIFE HISTORY AND INJURY.

Careful studies of the life history of this insect have been made by Armstrong in the Montreal district, Hammond in the Ottawa district, and Gray in Alberta. All three reports are included in the Ontario Entomological Society Report for 1923. Local observations from year to year at Macdonald College have been quite in harmony with the findings of Armstrong in Montreal.

The onion maggot overwinters in the pupal stage and the first of the adult

flies emerge from the middle to the end of May. Normally, in the province of Quebec, the first emergence is after the third week in May and the maximum emergence around the second week in June. Armstrong records the average preoviposition period as being 11.25 days. The preoviposition period varies somewhat in relation to climatic conditions.

There are two full generations of the onion maggot yearly and a partial third. While there is considerable overlapping of the broods the greatest number of eggs are to be found in the field during June and August. Mr. Stewart found the height of the oviposition period of the first generation to lie between June 5th and June 15th.

The eggs are deposited on or around the base of the onion plant and hatch in about 4 or 5 days. The first generation larvae mature in 8-19 days while the larvae of the second generation may take from 9 days to a month to complete their growth.

First generation pupae usually mature in about 15 days. A considerable number of the second generation pupae do not give rise to adults until the following spring. Over 90% of pupation occurs in the soil.

In 1923 Armstrong recorded 1st generation eggs, larvae, and pupae as prevalent in Quebec from May 30th to Aug. 20th; second generation eggs, larvae, and pupae present from July 20th to October 4th, and stages of the third generation appearing from September 8th to the close of the season.

Injury is first detected by the drooping of the seedling onions, which is first noticeable about the middle of June. Many will have wilted and died by the middle of July. In young plants the injury usually causes the whole top to die and in older plants the burrowing of the maggots into the bulbs frequently causes rot to develop so that the onion becomes unfit for market. As it is the spring brood, however, which causes by far the greater damage control efforts are usually largely confined to attempts to check injury from this generation.

7.—RELATIVE RESISTANT POWERS OF DIFFERENT VARIETIES OF ONIONS TO MAGGOT ATTACK.

It was thought that perhaps some varieties of onions would have a greater attraction to the females for oviposition or that some varieties would offer greater resistance to maggot attacks. The following varieties were tested and counts made of the infestation. It is noted that these varieties showed very little difference in degree of infestation.

Variety	*Infestation*
Ohio Yellow	2.1%
Southport White	2.5%
Southport Yellow	2.7%
Australian Brown	3.2%
Yellow Globe Danvers	3.25%

8.—EFFECTS OF TEMPERATURE, SUNLIGHT, AND MOISTURE ON THE EGG.

The following experiment was carried out to determine the effect of temperature on the length of incubation period of the egg. The eggs were incubated on moist blotting paper placed in petri dishes. The eggs used in this experiment were collected from around the same onion plants every twenty-four hours, all the eggs being cleared away each time.

The following table shows the results of the experiment.

Number of Eggs	Approximate Temperature	Number of Days Required to Hatch		
		Minimum	Maximum	Average
25	60°F.	4	6	5.5
25	65°F.	4	6	5.5
25	68°F.	4	5	5.
25	71°F.	3	5	3.5
25	75°F.	2.5	4	3.5

From the above table it would appear that increase in temperature causes the incubation period to shorten. Eggs incubated under exactly the same conditions vary often in the number of days to hatch. Under ordinary laboratory conditions the majority of eggs hatched in four or five days.

In the field during the cool weather of May and June the incubation period should be longer than in the warm months of July and August, and from general observations this seems to be the case.

The following experiment was conducted to determine the effect of sunlight and dryness upon the egg:

Conditions of the Tests	Number of Eggs Used	Number of Eggs Hatched	Per cent of Eggs Hatched
On moist blotting paper exposed to strong sunlight in petri dish	40	7	17.5%
On dry blotting paper exposed to strong sunlight in petri dish	35	0	0
On moist sand exposed to strong sunlight in petri dish	50	16	32.0%
On dry sand exposed to strong sunlight	30	2	6.6%
On moist blotting paper in shade in petri dish	75	62	82.7%
On dry blotting paper in shade in petri dish	50	12	24.0%
On blotting paper and placed in humidity jar	50	41	82.0%
On blotting paper and placed in desiccator	80	0	0

From the above table it is apparent that sunlight and dryness play an important role in preventing the development of the embryo within the egg. This role is probably one of desiccation, although direct sunlight may affect the egg in other ways.

During the hot, dry weather of July and August many eggs fail to hatch owing to the dryness of the soil and exposure to the direct rays of the sun. In examining the soil around onion plants many eggs are noticed lying exposed on the surface of the soil. This condition may be brought about by the winds blowing the soil from off the eggs, cultural operations, or washing away of the earth by a shower.

Eggs that had been in the desiccator for eight days were placed under normal conditions but failed to hatch, showing that under such extreme conditions they could not be revived.

Excessive amounts of moisture did not seem to have any detrimental effects upon the egg. Eggs totally immersed in water, hatched normally but the resulting larvae soon died if not removed from the water.

Observations during the course of the above experiments showed that moisture conditions surrounding the egg do not influence the incubation period but rather the percentage of hatch.

9.—THE HABITS OF THE LARVAE.

The onion maggot apparently restricts its feeding habits to onions, garlic and the leek. The common weeds and cultivated plants about the onion plots were frequently examined for onion maggots but without results. The larvae were introduced into the stalks and roots of many weeds and plants but they soon died without apparently feeding.

Because of the similarity which exists between the Onion Maggot (*Hylemyia antiqua, Meig.*) and the Cabbage Root Maggot(*Phorbia brassicae,* Bouche) attempts were made to rear the onion maggot on cabbage and the cabbage maggot on onions. All attempts failed. Attempts were also made to rear the onion maggot on lettuce, but the maggots died shortly after being introduced.

From many observations made during the course of experiments on the larvae, it was noticed, that frequently some larvae would pupate before becoming full grown. Several experiments were conducted in which larvae slightly over half grown were induced to pupate. This phenomenon was brought about by cutting off their supply of food, in which case, quite a number would go into pupation. Thus in the field it is possible that half grown larvae may pupate if their food fa ls, and thus carry themselves over such a period.

i

Onion Maggot Migration.

The question has often arisen whether the maggot confines its operations to one plant or whether it will migrate from plant to plant. Frequently the

number of eggs laid at a single plant is very large, so large that the resultant larvae could not be sustained by it. On May 28th 112 eggs were gathered from a single plant and commonly as many as thirty or forty. However at this time of year, the onion plants are far too small to support such a number. The average number of maggots per seedling runs from four to six, while a greater number could be maintained by a larger plant. If the great majority of the larvae are to survive they must be able to migrate from a plant, which is failing them in food supply, to a fresh one. The eggs are usually placed within an inch or so of the plant and this would appear to be the limit to which a newly hatched larva can migrate.

A series of experiments were conducted to ascertain the extent of migration of the larvae and other activities beneath the soil. These experiments were carried out in duplicate and under as natural conditions as possible.

The Extent of Migration of Newly Hatched Larvae.

This experiment was carried out to find the extent of migration of newly hatched larvae to their food plant. Onion maggot eggs were placed on the soil of a flat containing onion seedlings, so that they would be between the source of light and the plants. This precaution was taken because of the negative phototropism exhibited by the larvae.

The following table sets forth the results when the eggs were placed at varying distances from the plants.

Number of Eggs Used	Distance Placed From the Plant	Number of Maggots Reaching Plant
15	0.5 inches	12
15	1.0 "	9
15	1.5 "	1
15	2.0 "	0
15	2.5 "	0
15	3.0 "	0

From the foregoing table one-half inch appears to be the optimum distance while one inch the maximum distance which newly hatched larvae can migrate.

The following experiment was conducted in an effort to find out the manner in which the maggot reached its host plant.

Seedling plants were used and twelve newly hatched maggots were placed within half an inch of the plants. Most of the maggots began burrowing into the soil immediately. The operation of burrowing consists of thrusting the anterior portion of their body into the soil while the posterior portion of the body described circles in the air, the whole presenting a wriggling motion.

This operation takes considerable time and it was nearly two hours before all the maggots were beneath the soil. In twenty hours the maggots were in the bulbs.

Eggs were also placed in the axils of the leaves. Upon hatching the larvae entered the leaves and worked their way down to the bulb, feeding as they progressed.

The Extent of Migration of Half Grown Larvae.

Several experiments were carried out with regard to the distance half grown larvae would migrate and any factors which might influence migration.

Twelve half grown larvae were selected and placed on the surface of the soil sixteen inches from onion plants in such a position that they would have to travel towards the sunlight in order to reach the plants. A few of the maggots burrowed into the soil but the majority began to crawl along the surface away from the source of light in the opposite direction to the plants. Upon examination two hours afterwards they were still moving away from the plants.

The phototropic and chemotropic responses were considered to the following extent. The maggots were arranged as before with regard to their food plants and the source of light. Trails were made from the maggots to the onion plants by saturating the surface soil in strips with an infusion of onions, The maggots however were not attracted to the onions by means of these trails, and were found to be crawling away from the onions and the source of sunlight.

The maggots were now placed twenty-six inches from the onions in such a position that in moving away from the source of sunlight their course was directed towards the plants. A few of the maggots burrowed into the soil while the remaining migrated over the surface of the soil. At the end of two hours the maggots had reached the plants and were burrowing into the ground at their base.

The Extent of Migration of the Larvae from Plant to Plant.

The following experiments were instituted to obtain data on the migration of the maggots from plant to plant.

Two flats were set out with six onion plants in each. The plants were placed seven inches apart and numbered as shown. Forty eggs were placed around plant marked "1". In the first flat, fourteen days afterwards, the plants were examined. This length of time was allowed so that plant marked "1" would be more or less consumed and the maggots induced to migrate in search of further food supply.

The following results were obtained from the first flat. Plant No. 1 was heavily infested and reduced to a sodden mass of decaying material.

No. 3 x (0)	No. 4 x (1)
No. 2 x (3)	No. 5 x (1)
No. 1 x (15)	No. 6 x (9)

In the second flat thirty eggs were placed around plant marked "i". Upon examination ten days afterwards plant No. 1 was heavily infested and reduced to a sodden mass.

No. 3 x (0)	No. 4 x (1)
No. 2 x (3)	No. 5 x (1)
No. 1 x (12)	No. 6 x (5)

Two other flats were set out with fifteen onion plants placed four inches apart. In the first flat a hundred eggs were placed around the central plant marked "8". Fourteen days afterwards the plants were examined and the following results obtained.

No. 5 x (0)	No. 6 x (1)	No. 11 x (1)
No. 4 x (0)	No. 7 x (2)	No. 12 x (1)
No. 3 x (4)	No. 8 x (35)	No. 13 x (39)
No. 2 x (1)	No. 9 x (8)	No. 14 x (0)
No. 1 x (0)	No. 10 x (0)	No. 15 x (1)

In the second flat ninety eggs were placed around plant marked "8". This flat was examined fourteen days afterwards with results noted below.

No. 5 x (0)	No. 6 x (0)	No. 11 x (1)
No. 4 x (0)	No. 7 x (2)	No. 12 x (2)
No. 3 x (3)	No. 8 x (33)	No. 13 x (21)
No. 2 x (1)	No. 9 x (10)	No. 14 x (2)
No. 1 x (1)	No. 10 x (3)	No. 15 x (2)

The degree of migration of the maggots along a row of seedlings was next investigated. Twelve seedlings were planted in a row, one and one-half inches apart in the row. Fifty eggs were placed around an end plant marked "1". These seedlings were examined in fourteen days time. The first nine plants were attacked by the maggots, while the others were uninfested.

From the experiments on larval migration from plant to plant, it is evident that newly emerged larvae can travel but a short distance, one inch being probably the maximum. Larvae that have attained partial growth can and will migrate considerable distance to more suitable environment. The tendency of migration is away from the source of light, rather than in any definite direction to a plant. One heavily infested plant may be the origin of infestation to a number of plants in its immediate vicinity, especially if the plants are close together. Onion plants in the seedling stage probably suffer more as a consequence of migration of maggots than when they are more advanced in growth. Estimates from the above experiments show that about fifty per cent of the maggots migrated successfully from a heavily infested plant while about 7 per cent were lost.

10.—RESULTS OF EXPERIMENTS WITH THE PUPAE.

It has been noted that pupae under the same conditions behave differently. Pupae in the same breeding cage and subject to similar moisture, temperature and other environmental conditions do not develop in the same length of time.

The following experiment was conducted to obtain data on length of pupal stage, variation in length of pupal stage, mortality and presence of parasites.

On June 30th, two hundred newly formed pupae were placed with moistened sand in a cage. The following table sets forth the results.

Date of Emergence	Number Emerged		Parasites
	Male	Female	
July 14th	59	34	0
July 16th	40	49	0
July 18th	3	2	0
Mortality 6.5%			

From the foregoing figures, it is seen that nearly half of the flies emerged on the fourteenth day, and practically all the others on the sixteenth day. Five took eighteen days to complete their development, making a range of four days, thus at least five showed quite a difference in rate of development. The mortality was 6.5 per cent and from this lot no parasites were recorded.

The Effects of Moisture on Pupal Development.

Severe or unfavorable conditions affect certain individuals differently, some are more able to withstand these conditions than others. In the following experiment on moisture in relation to pupal development it is noted that with fifteen pupae placed in oven-dried soil and maintained in this condition, two pupae were able to withstand the desiccation while the others could not. Under optimum conditions there probably exists a normal period of development, and under abnormal conditions a disparity in development.

In this experiment newly formed pupae were placed in vials, each vial containing a hundred drams of oven-dried soil. Water was added to the vials to give the various percentage of moisture. Fifteen pupae were placed in each vial and the whole weighed and tightly stopped with cotton. Weighings were made each day and water added to make up losses through evaporation.

Lot Number	Percentage of Moisture	Number of Adults Emerging	Percentage of Adults Emerged
1	0%	2	12.3%
2	2%	9	60.6%
3	4%	14	93.3%
4	8%	13	86.6%
5	16%	12	80.0%
6	32%	8	53.3%
7	48%	1	6.6%

From the above data 4 per cent moisture seems to be the most favorable for pupal development, while a high percentage of emergence was obtained in the vials ranging from 4 per cent to 16 per cent. The soil in the vial containing 32 per cent of moisture was practically saturated. The soil in the vial containing 48 per cent of moisture was supersaturated. It thus appears that within wide limits, soil moisture does not seriously affect pupal development.

A dish of oven-dried soil containing ten pupae was placed in a calcium chloride desiccator. The pupae were unable to withstand the desiccation and no flies emerged.

Effect of Temperature.

Gradual increases in temperature will hasten pupal development, while extremes in temperature will retard development, until such a point in temperature is reached where development ceases. During dry hot periods in summer, emergence is retarded until favorable conditions arise. This explains. somewhat, the variation from year to year in the number of flies present in the field during July and August. It has been noticed that the adults of the second brood are frequently delayed in emerging and that these may be delayed for some weeks and perhaps not appearing until September and thus swelling the numbers of the third generation flies. This occurrence is not incidental but in close relationship to the existing climatic conditions

11.—THE HABITS OF THE ADULT FLIES.

The adults of the onion maggot can be successfully reared by supplying them with a solution of molasses, diluted with water, or sugar syrup. The flies are readily attracted to these substances and feed upon them eagerly, if hungry. In field experiments it will be noted that the most attractive substance for the flies was a solution of cane molasses.

The onion flies feed at the blooms of many of our flowering plants. The blossoms of the dandelion seem to have a very great attraction for the flies, both male and female. The blossoms of fruit trees and the various common weeds such as buttercups, golden-rod, hawkweed, mallow, milkweed, mullein, mustards, wild parsnip, pigweed and sweet clover are visited frequently. Nevertheless the dandelion bloom still holds a greater attraction to the flies and on introducing mixed bouquets of flowers into cages containing the flies, the dandelion flowers are usually visited first and in greater numbers than the other flowers.

During the emergence of the first generation flies the dandelion bloom is very prevalent and would supply an unlimited supply of food, The flowers are again in evidence when the flies of the second generation emerge.

From numerous field observations made there seems to be no doubt but that the dandelion blossoms are a source of food supply which is very attractive

to the adults. On bright, warm, sunny days they may be seen flying from blossom to blossom. When feeding the anterior part of the insect is hidden in the bloom and only a portion of the abdomen is visible.

In experiments where the flies were given access to flowers the length of life was from three to four weeks (one female living 43 days), while the length of life of flies not given access to flowers was from 5 days to a week. In the cages provided with flowers copulation and oviposition took place, with egg fertility ranging around 92-3%, while in cages not provided with flowers copulation and oviposition was not recorded. Dandelion flowers, by themselves, are quite sufficient as a source of food supply for the flies, normal development taking place.

Sunlight and warmth are essential to mating and oviposition. In cases where the flies were kept from the presence of sunlight they remained more or less inactive and did not mate, and no eggs were laid. Observations clearly demonstrated the existence of a pre-oviposition period, which under cage conditions extends from 13 to 17 days, and to 23 days in the case of one cage. The preoviposition period varies somewhat in relation to climate conditions, but tends to be fairly constant under uniform conditions. Under field conditions, the preoviposition period probably occupies about two weeks and the oviposition period about 10 days. Cold weather would have a tendency to lengthen these periods, while warm weather would shorten them considerably.

Before egg laying commences the adult females pass through the preoviposition period referred to above and during this time feeding and mating takes place. Newly emerged flies placed in cages in the morning were noticed copulating in the afternoon. The act of copulation is of short duration.

The proportion of male to female flies emerging is fairly even, with perhaps a larger number of males present in the field during the beginning of the emergence period and a greater number of females present during the latter period. This may be at least partly accounted for by the fact that the females as a rule live several days longer than the males. When the right conditions of food, moisture, and sunlight are present egg-laying commences about two weeks after emergence and lasts for some two weeks and during such favorable weather conditions the female flies will be seen resting on the onion plants and crawling over the surface of the soil, apparently looking for suitable places to deposit their eggs.

Egg laying.

The time of the day that egg laying takes place is controlled largely by climatic conditions. During the cool portions of the morning and evening the flies are not very active, but the activities increase with increasing temperature. On extremely hot days, especially in dry weather, more eggs are laid directly after the period of excessive heat.

The first generation females usually select plants that have attained considerable growth around which to lay their eggs. Thus during the earlier part

of the spring, volunteer and trap onions are heavily infested, while the young seedlings are untouched. In 1925 eggs were taken in considerable numbers from around the trap onions on May 22nd, but it was not until June 2nd that eggs were taken from the seedlings. Trap and volunteer onions are invariably heavily infested as long as they are available in the field.

Onion plants whose bulbs are set deep in the ground with their leaves branching out from near the surface of the soil prove more attractive for oviposition than those sets in which the bulbs have a distinct "neck" and where the leaves branch off some distance above the surface of the ground.

Second generation flies often select plants that have already been attacked or are diseased. Onion plants infected with onion smut are very often heavily infested with maggots, the stronger odor of the diseased and decaying onions apparently offering a greater attraction for egg laying.

Freshly plowed or cultivated soils are sometimes more heavily infested. This is probably due to the moisture conditions of such soils.

The eggs are generally laid just below the surface of the soil, within an inch or so of the plant. During the warm days of mid-summer the eggs are usually found in the soil on the shaded side of the plant. During the last week of July and through August, however, the eggs are often laid in great numbers in the axils of the leaves. The eggs are also found in this position, in great numbers, immediately after heavy rains. If the soil around the plants is hard the eggs are deposited in the crevices in the soil about the plants. Large numbers will be found in the opening formed at the surface between the onion stalk and the ground.

The act of the fly laying her eggs in close proximity to the host plant and slightly under the soil is one of instinct, which insures a large number of the newly hatched larvae reaching their source of food and against destruction of the eggs through lack of moisture and exposure to the direct rays of the sun. Any eggs seen on the surface of the soil is probably due to accident.

On rainy days and during cold weather egg laying ceases. Just before a thunderstorm the flies are inactive and oviposition interrupted. Sometimes a day elapses before egg laying recommences. On warm, windy days more eggs are laid than would be expected. This is due to the fact that the females seek shelter in crevices about the onion plants and during their stay many eggs are laid in these pockets.

Act of oviposition.

During the height of the oviposition period many of the females appear to be in a highly excited and nervous state. They will be seen on the onion plants moving quickly from place to place. This condition appears to be an indication that oviposition is about to take place. If a fly be disturbed or dissatisfied with the plant, she will immediately fly to another. When, after a close examination, the plant suits her needs, she will run quickly down the

stalk to the ground. Here she will encircle the plant several times, examining the ground very thoroughly for a suitable place to lay her eggs. When a spot is located which apparently fulfils her requirements, she will insert her ovipositor and feel about with it. If the right spot cannot be found around a plant, she will fly or crawl to another nearly plant. The fly exhibits a great deal of care in selecting a place to deposit her egg. She will examine the soil around a dozen or more plants until a suitable location is found. When crawling about the ground her ovipositor is often somewhat extended and dragging on the ground. When a suitable spot is detected, she will back up to it and immediately burrow her ovipositor gradually into the soil. When a sufficient depth is reached, she pauses a moment before laying an egg. After the egg is laid, the female may fly to another place or remain in the same place and continue to lay eggs. One fly under observation laid eight eggs in one hatch. The time occupied was some fifteen minutes.

12.—ON TYPES OF SOILS IN REFERENCE TO ONION MAGGOT INFESTATION.

Introduction.

In looking over numerous onion plots, attention is attracted by the "patchy" appearance of many of the fields. Some spots in a field being heavily infested with the maggots while other portions are relatively free from attacks. Examination of these fields from year to year indicate that the "pattern" and position of infested areas are frequently the same, depending of course on the general prevalence of the insects.

The thought therefore suggested itself that insects might have a certain preference in the selection of soils for oviposition, and that a preliminary investigation might yield data which would warrant more detailed study.

Selection and Method of Taking Soil Samples for Study.

The season selected was a comparatively light one so far as maggot infestation of onions was concerned, but satisfactory conditions (from an entomological standpoint) existed on the farm of Mr. McEvoy, at Rosemount, Montreal, to permit a study of the soil preferences of the maggots. In taking samples, considerable care had to be observed that smut injury should not be mistaken for maggot injury. Smut was quite prevalent in some fields, but where soil samples were taken, which were classed as infested types, care was taken to note the actual presence of the maggots, so as to eliminate as far as possible any chance of confusion with smut injury.

The following samples of soil were taken:

Sample A—From a field which had been uninfested by maggots for a considerable number of years, and for this reason had been planted to onions continuously. A composite sample was taken by mixing thoroughly soil obtained fron five different spots in the field. Care was taken that there was no

maggot infestation near the spots where the samples were obtained. An uninfested soil sample.

Sample B—From four "patches" infested with maggots. An infested soil sample.

Sample C—From the half of a field which was badly infested with smut and maggot. This section of the field had been top dressed with manure the previous fall, the fertilizer having been plowed under in the spring before planting the crop. An infested soil sample.

Sample D—From same field as "C" but the other half. This half of the field was top dressed at the same time as the first half in the fall, but the dressing was not plowed under in the spring owing to lack of time. The crop was good and showed very little damage from maggot, in marked contrast to the other half. Composite sample from four places. An uninfested soil sample.

Sample E—From the same portion of field described in "C" but from uninfested spots which occurred therein. Composite sample from three places. An uninfested soil sample from an infested field.

Sample F—From an onion field in an old orchard. Composite samples from five spots well in the field. This field was new ground for onions and the infestation was not heavy. Some trouble from cutworms was experienced in June. An uninfested soil sample.

Sample G—From the same field as "F", but from one corner where maggots had srtuck in a little. An infested soil sample from a field with a very low infestation.

Sample H—From badly infested areas in one of the fields. A considerable percentage of the injury in this region was due to smut. An infested soil sample.

Sample I—From same field as "H" but from uninfested end of field. An uninfested soil sample.

All the above samples were taken on the same afternoon.

As the attracting or repelling principle (if any) would be located in the upper layers of soil, the samples were not taken deeper than four inches. The majority of the maggots would be found above this depth normally in any case. The spots selected were pressed with the foot to firm the soil, and an ordinary drinking glass pressed down into the ground and the soil within the circle formed by the glass carefully scooped up and placed within a paper bag.

Poison bait pans were used throughout the fields, but with the exception of the field from which sample A was obtained, were placed out at too late a date to be a very much practical value. The first flies were noticed emerging on May 20th, and the pans were not put out for at least a month later. In the upper field of sample A the pans were out early in June, but as this had always been a field with singularly small maggot infestation it is doubtful if the degree of injury was affected thereby to any appreciable degree.

Trap onions were employed in the fields where samples C, D, E, H and I were obtained.

Method of Making Physical Analysis.

The method of analysis was similar to that outlined in Chapter VI, "Soils", by Lyon, Fippin and Buckman.

The name of each separate and the size of particles in it are as follows in the U. S. Bureau of soils classification:

Name of Separate	Diam. of Particles
Fine gravel	1. — 2. mm.
Coarse sand	.5 — 1. "
Medium sand	.25 — .5 "
Fine sand	.10 — .25 "
Very fine sand	.05 — .10 "
Silt	.005 — .05 "
Clay	.0000 — .005 "

Results of Physical Analysis.

The preliminary sifting of the entire sample, to remove any matter over 2 mm. (classed as gravel), yielded the following percentages of that separate:

A	8.33%
B	4.00%
C	15.55%
D	12.36%
E	11.11%
F	9.03%
G	6.43%
H	7.24%
I	6.55%

Duplicate samples were then analysed to find the relative percentages of sand, silt and clay. From these samples the gravel had already been extracted as indicated above.

The following percentages of these three separates were obtained.

Sample	Sand	Silt	Clay
A	81.10	12.96	5.94
B	77.27	13.39	9.34
C	77.49	15.75	6.75
D	78.33	14.43	7.23
E	78.30	14.84	6.85
F	70.35	21.79	7.85
G	78.75	14.69	6.55
H	82.54	11.51	5.94
I	75.28	17.46	7.25

The finer sand separates of samples "A", "C", and "D" were also obtained as representative of uninfested and infested soil. It was thought unnecessary to carry the other soil samples further through the somewhat tedious process unless results from the three selected might appear to warrant it.

The following figures were obtained for these separates:

Separate	A	B	C
Fine gravel	.276	.209	.420
Coarse sand	.786	.937	1.057
Medium sand	1.675	1.327	1.090
Fine sand	.435	.393	.421
Very fine sand	.891	1.026	.953
Totals	4.063	3.892	3.941

The above represent the average actual weights of the separates in five grams of soil.

From the above the average percentages of sand, silt and clay for infested and uninfested fields would be as follows:

	Uninfested	*Infested*
Sand	76.671%	79.017
Silt	16.296	13.835
Clay	7.024	7.145

In comparing the soils taken from infested and uninfested plots it was found that the percentage of the soil separates, i, e., from gravel to clay, was not a controlling factor influencing the degree of infestation. The predominance of any one separate or group of separates, such as would normally occur in fields suitable for the growth of onions, did not render a field more liable to possible onion maggot infestation.

Degree of Acidity of Soils:

In order to obtain as much data as possible, tests to determine the relative acidity were made of all the nine samples of soils which were subjected to the physical analyses already described.

The tests revealed the following figures for uninfested and infested soil:

Uninfested Soils:—Sample	A	7.0 pH.
"	D	6.8 pH.
"	E	6.8 pH.
"	F	6.6 pH.
"	I	6.8 pH.
	Total	34.0

Infested Soils:	Sample B	6.8 pH.
	" C	6.9 pH.
	" G	6.8 pH.
	" H	6.8 pH.
	Total	27.3
	Average pH for uninfested soils	6.8
	Average pH for infested soils	6.825

Loss from Ignition:

When the original samples were tested for the percentage of combustible matter, the following duplicated results were obtained:

A	14.48%
B	7.62"
C	10.20"
D	14.25"
E	11.30"
F	10.56"
G	7.94"
H	6.52"
I	9.86"

The average percentages for infested and uninfested soils would be therefore:

Uninfested	12.09%
Infested	8.07%

It will be noted that no uninfested soil had a percentage of combustible matter as low as the average for infested soils, and that no infested soils had a percentage as high as the average for uninfested soils.

The plowing under of the top dressing of "C" would be expected to result in a lower figure than "D" where the manure was not plowed under but only mixed with the surface layer in the ordinary course of cultivation by harrows, hoes, etc.

13.—HISTORICAL REVIEW OF CONTROL MEASURES.

The control of the onion maggot has proved to be a very difficult problem. The life habits of the insect are such that the ordinary methods of control have been useless, and special remedies have had to be sought.

The maggot itself lives within its host plant, where it cannot be reached without danger of injury to the plant. The eggs are laid just beneath the soil and close to the plant. The pupae are formed in the soil, often at a depth of five or six inches. These stages of their life history offer very little scope for the application of control measures.

The adult female fly presents the best and apparently the only means of

attack, and it is in this stage that the best results have been secured within recent years.

Since a very early date numerous schemes have been devised and tried out, only to be discarded as worthless. Dewdney (1) in 1840, suggested the use of nitrate of soda on the beds.

In 1879, Eleanor Ormerod (6) suggested the use of wood ashes and garden refuse as manure. Again, in 1883, (8) she advised the following remedies.

1. Banking up of the onions with earth.
2. Thick dressing of mustard cake to attract the flies for egg laying.
3. Quick lime and salt as a dressing.
4. Application of lime and dry soot.
5. Sprinkling with water and paraffin oil.

During 1891 various other measures were put forward as possible means of of control. Fletcher (11) mentions spraying with kerosene emulsion along the rows, while Fernald (10) favoured the scattering of pulverized gas lime along the rows, watering with liquid from pigpens and the killing of infested plants and maggots with carbolic acid or kerosene oil.

A few years later J. B. Smith (12) applied kainit with some results.

The spraying of the plants with carbolic acid emulsion to act as a repellent was recommended. This gave good results, especially on small onion plots. However, on a large scale frequent treatments with this material entails a large amount of time and labour, causing this method to be impractical for commercial purposes.

In 1907, J. B. Smith (15) made use of small early plantings of onions to act as a trap crop, and as soon as these were found to be infested they were removed or destroyed. A modification of this system is now employed extensively in conjunction with other control measures and decreases considerably the infestation of the main crop.

A considerable number of soil insecticides have been tested to ascertain whether some substance could be found which would tend to reduce the first-brood maggot infestation on the young onions. Such materials as powdered hellebore, tobacco dust, dry lime sulphur, carbolated lime, calcium hypochloride, Derris, Black leaf 40, pyrethrum insect powder and others have been used at various times.

Certain mineral fertilizers (17) have been tried as deterrrents to the fly. In 1923, Smith, K.M., (31) claimed to have obtained good results when he used precipitated chalk as a carrier for tar oils and applied to the soil. Again in 1925 (33), he obtained some success with nicotine sulphate dust in a 5 per cent mixture with precipitated chalk. Spraying the young plants with a Bordeaux oil emulsion (32) is now being given consideration.

Insecticide applications against underground insects are rarely satisfactory because of the difficulty of getting them into contact with the species to be dealt with. A certain substance may kill the maggots well enough, and placed

FIG. 1.—Section of an onion field where maggot infestation was very heavy. This field had been top-dressed with manure, plowed, and then harrowed, previous to the sowing of the crop.

FIG. 2.— A parallel section of the same field as that shown in fig. 1. Maggot infestation very light. This soil had received essentially the same treatment as that portion of the field shown in fig. 1, but had not been plowed. As a result the added organic matter was left in the upper layers of the soil.

FIG. 3.—A field that had never shown any appreciable maggot injury to onions although onions had been grown here for several years. Part of the same farm as field shown in figs. 1 and 2. This field showed a high percentage of combustable matter in the upper layers of the soil.

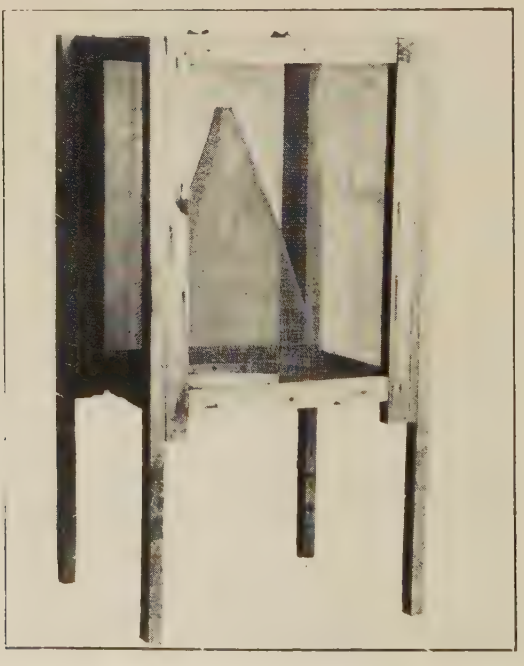

FIG. 4. Type of fly cage used in determining the relative chemotropic responses of adult flies, particularly the onion root-maggot.

in the hands of competent workmen will perhaps effect a control. While some of the substances used as soil insecticides or repellents were rather efficient, they are perhaps more useful as garden remedies than in field operations. Besides other considerations which prevent their general use, such as initial cost and expense of preparation, etc., the value of these materials depend on the number and thoroughness of the applications and are directly influenced by rainfall. The high cost of labour and the time consumed in frequent use counteracts, in a large measure, their value in the field.

Sanders (18) in 1913, attacked the problem from an altogether different angle and endeavoured to lure the female fly to a poisoned bait spray before egg laying began. The bait consisted of molasses diluted with water and sodium arsenite. This method was suggested to him by the results obtained by Severin (19) in his work on the control of fruit flies. The following year Severin (20) carried on further experiments with the poisoned spray and obtained promising results. During 1916, Howard (24) investigated the poisoned bait as a control for the onion fly. He, however, dispensed with the spray and distributed the bait in pans about the field. Bourne and Fernald (25) made use of baited traps to capture the adult flies. This system would not appeal to most growers, because of the amount of apparatus necessary and the inconvenience in handling.

In Canada, the poison bait spray was first tried during the years of 1916-17 (23) and warranted further trials.

During the season of 1921, control with sodium arsenite as a bait and spray was conducted by Prof. W. Lochhead and Mr. W. J. Tawse (26) in the Montreal district. They found that the poisoned bait placed in pans was the more efficient and economical.

Treherne and Ruhmann (27) did not get satisfactory results in their trials with poisoned baits and resorted to the use of trap onions as the most effective remedy in the "dry belt". The failure of the bait was possibly due to the presence of water in the irrigation ditches attracting large numbers of flies away from the poison.

In 1923 (30) control with the sodium arsenite bait was again carried out in the Montreal district. A combination method consisting of the poisoned bait placed in pans and trap onions as suggested by W. J. Tawse (30) was also tested. The results were very promising and gave every indication of being a success.

The use of the combination trap crop and poisoned methods of control have been practised generally throughout the onion growing districts for some time, as, until lately, these methods were found to be the most practical and efficient remedies known.

Flint and Compton in Illinois (35) in 1925 claimed practically complete control of the onion maggot by the use of Bordeaux oil emulsion. During this year, in their locality, the maggots had caused a loss of at least 50% of the onion crop. The mixture was applied in a fine stream directly onto the young onions

in the rows and in sufficient amount to wet the ground for a short distance on either side of the plants. The first application was made when the onions were about an inch in height. Two to four subsequent applications were made at 7-10 days intervals. Moistening the onions with corrosive sublimate solution was also found effective.

14.—FIELD EXPERIMENTS OF 1924 AND 1925 TO DETERMINE THE RELATIVE CHEMOTROPIC RESPONSES OF DIPTERA TO CERTAIN SUBSTANCES, WITH SPECIAL REFERENCE TO THE ONION MAGGOT.

The poisoned bait method of controlling the onion maggot is based on the fact that a preoviposition period of some ten days exists and during this time the female flies feed before egg-laying commences. Poisoned material is placed in the field, which attracts the flies for feeding purposes. The female flies, feeding upon this bait, are thus killed before they are able to deposit their eggs in the vicinity of the onion plants.

Previously the bait used with the greatest success was one made up according to Sander's formula (18),

Sodium arsenite	¼ ounce
Molasses	1 pint
Water	1 gallon

The lethal principle of the bait consists of the soluble poison sodium arsenite, while the attracting factor is the molasses. In tests of the killing power of this bait, it was found that fifty percent of the flies were killed during the first 24 hours. The remainder died within 48 hours after having access to the mixture. (18).

The attracting power of a mixture of molasses and water for the flies is very high, but upon the addition of sodium arsenite this is reduced somewhat. A long series of tests was made of various substances to find which might prove to be of greatest value as attractants, as poisons or combinations of both. It was thought that some chemical might be discovered which would considerably increase the chemotropic response of the adult onion maggot to them.

Method.

The materials to be tested were put in petri dishes containing wads of cotton batting and then transferred to the onion plots. Minnesota fly traps were placed over the dishes, with the bottoms of the traps raised about two inches above the ground. The number of flies caught in the traps was used as an index of the attractiveness of the various substances used. It is possible

that all the flies which visited the baits did not enter the traps. The number escaping however is probably small and would not affect the comparative figures obtained, so that it can be disregarded.

The experiment was not started until August 2, owing to the delay in securing the necessary equipment. Fifty-five different baits were tried over periods of varying length, the number of trials depending on the promise shown by the material. The traps were examined at frequent intervals, the flies removed and killed. The baits were replenished when necessary. Each catch was kept separate and counts made of the males and females of the onion maggot fly, but the other flies were counted in toto. Check traps using molasses diluted with water, and water alone as baits were run throughout the entire period of investigation.

Weather conditions played an important role in the number of flies caught. As would be expected, a bright warm day gave more flies than a day that was cool or cloudy. During rainy spells the flies are more or less inactive and not attracted to the traps. The occurrence of rain gave some trouble by diluting the baits or causing an overflow in the dishes. The catch also varied from day to day due to seasonal prevalence of the flies.

The relative position of the traps in the field was changed from time to time, but this did not prove to be a factor causing increase or decrease in the numbers of flies attracted to the traps.

The traps were tried at various distances above the ground in order to ascertain at what height they would be most efficient. Molasses diluted with water was used as the attractant. The results obtained at the experimental traps were compared with those obtained from check traps, which were kept at a height of two inches above the ground. This test was carried on from August 27th to October 2nd. Counts were kept of the onion maggot flies (male and female) and all miscellaneous Diptera. The number of flies caught at each trial by the check traps were given a value of 100% and the numbers caught at the experimental traps were compared to these figures on a percentage basis. Those traps with the bottoms raised two inches above the ground secured the greatest catch.

Results of the Field Experiments.

In the course of the following experiments which covered the period of August and September some 2905 adult onion maggot flies were recorded. Of these, 1767 were females and 1138 were males. Generally the number of females caught outnumbered the males, although on some days this was reversed.

The number of miscellaneous flies taken approximated nearly 20,000 individuals, representing many species.

Traps baited with the following oils showed them to be of very little value

as attractants and in some cases probably acted as repellents. The extent to which they might act as repellents was not investigated.

Kerosene	Oil of Hemlock
Oil of Anise	" " Lemon
" " Camphor	" " Mustard
" " Cedarleaf	" " Nutmeg
" " Cinnamon	" " Origanum
" " Citronella	" " Pulegii
" " Cloves	" " Sassafras
" " Rose of Geranium	" " Spruce

Other organic compounds tried, which did not prove successful as baits, were ethyl alcohol, ethyl acetate, methyl acetate, acetic acid, butyric acid, formic acid, and lactic acid. The volatility of these substances rendered them unattractive after a day, even during the first day small catches were secured. The necessity of constantly refilling the dishes makes the use of these materials impractible and costly in labor and materials.

The general average catch was very low for the materials used as compared to the checks. Apparently they possess very little value as baits. (For the sake of brevity the rather extensive tables etc., are omitted as the evidence contained therein is negative in character).

Results with Sweetened Poisoned Baits.

The following group of inorganic poisons: ferric chloride, sodium fluoride, sodium cyanide and mercuric chloride were tested over a long period. These chemicals were made up into baits using by the same formula as described for sodium arsenite. Traps baited with sodium arsenite were run in conjunction with this experiment and used as a basis for comparison. A bait made up of molasses and water of the same concentration as the above was adopted as a check. The experiment was started on August 2nd, and run continuously until August 19th, when the tests with ferric chloride, sodium fluoride and mercuric chloride were discontinued. Sodium cyanide which showed the greatest promise as a bait was continued along with sodium arsenite until October 6th.

Tables 1 and 2 contain the summarized results of the number of onion maggot flies and miscellaneous flies caught up to August 19th. It is interesting to note the similarity between the relative numbers of onion maggot flies and miscellaneous flies attracted to the various baits. The data included in the two tables shows, that in both the number of onion maggot flies and miscellaneous flies attracted, the sodium cyanide bait is far superior to the others. Sodium arsenite, ferric chloride and sodium fluodride may be ranked together, while mercuric chloride is far below these in value.

TABLE 1.—The Number of Onion Maggot Flies Attracted.

Materials Used	Total Catch				Per Cent	
	Expt. Traps		Checks		Expt. Traps	
	Male	Female	Male	Female	Male	Female
Sodium Arsenite	33	73	138	132	23.9	55.3
Ferric Chloride	37	72	138	132	26.8	54.3
Sodium Fluoride	45	55	138	132	32.6	41.7
Sodium Cyanide	141	104	138	132	102.2	78.8
Mercuric Chloride	15	69	138	132	10.9	52.3

TABLE 2. —The Number of Miscellaneous Flies Attracted.

Materials Used	Total Catch		Per Cent.
	Expt. Traps	Checks	Expt. Traps.
Sodium Arsenite	529	2096	25.2
Ferric Chloride	407	2096	19.4
Sodium Fluoride	671	2096	32.0
Sodium Cyanide	2187	2096	104.3
Mercuric Chloride	221	2096	10.5

TABLE 3. —The Number of Onion Maggot Flies Attracted.

Materials Used	Total Catch				Per Cent	
	Expt. Traps		Checks		Expt. Traps	
	Male	Female	Male	Female	Male	Female
Sodium Arsenite	74	156	329	372	22.5	41.9
Sodium Cyanide	295	242	329	372	89.7	65.0
Water	7	30	329	372	2.1	8.1

TABLE 4.—The Number of Miscellaneous Flies Attracted.

Materials Used	Total Catch		Per Cent.
	Expt. Traps	Checks	Expt. Traps.
Sodium Arsenite	1548	9355	16.5
Sodium Cyanide	5840	9355	62.4
Water	172	9355	1.8

The continued tests with sodium cyanide and sodium arsenite presented further proof of the superiority of sodium cyanide to sodium arsenite. A survey of the figures in tables 3 and 4 shows quite conclusively the value of the sodium cyanide bait to be very much greater than sodium arsenite in attractiveness. It is quite evident that the attracting power of molasses for the flies is reduced very little upon the addition of sodium cyanide. On the other hand, when sodium arsenite is added to molasses the latters usefulness as an attractant is decreased considerably. The difference in the number of flies caught by the two baits is quite outstanding. The sodium cyanide attracted 74.9 per cent more males and 35.5 per cent more females than the sodium arsenite. (But see Section 15).

Results from the Addition of Portions of Onions.

In connection with the tests on the attractiveness of the various baits, additional traps were run with the respective media where parts of the young onion plants were added. Owing to the limited supply of apparatus, trials were not made with the addition of pieces of onions to the poisoned baits. However, separate tests were made with diluted molasses and with water alone. Crushed onion leaves were added to one set while crushed onion bulbs were added to another. There was little or no difference between the attractiveness of the onion bulbs or onion tops.

As a rule the addition of pieces of growing onions to the molasses increased the attracting power of the bait about twice for each sex. The ratio between the number of females and males caught was apparently not altered upon the addition of onions. The increase in attractiveness of the onion and molasses baits over the sodium arsenite and sodium cyanide was about four times. The attractiveness of media containing portions of onions was increased after standing for a day or two. The addition of portions of onion to water alone increased the number of flies attracted many times, but not comparable to the total numbers attracted by the sweetened baits. Table 5 gives the results observed in detail.

Percentage of Gravid Females Attracted to the Baits.

In an attempt to determine the type of females attracted to the most important baits, some 262 individuals were dissected, and the number of eggs present in each was noted. The flies were taken over a period from August 3, to September 17, inclusive, representative catches being examined as shown by Table 6.

It will be noted that in all cases those flies having over twenty eggs present were more numerous than the spent females or those having under twenty eggs. Thus it would appear that the greatest percentage of females attracted to the baits were those which were gravid or at least carried over twenty eggs.

As for the attracting power of the two poisoned baits, sodium cyanide and sodium arsenite, as compared with molasses and water, taken purely from the gravidity of the females, there seems to be but slight differences. In the sodium cyanide bait traps, 69.4% of a total of 81 females examined carried over twenty eggs. In the sodium arsenite bait traps 76.6% of a total of 73 females examined carried over twenty eggs. In the case of molasses and water bait traps 71.1% of a total of 108 females examined carried over twenty eggs.

It was thought that the additions of portions of onion leaves or onion bulbs to the baits would have a tendency to attract a greater percentage of gravid females. Referring to Tables 6 and 7 it will be seen that this is not the case, for in those baits containing onion leaves or onion bulbs, there is no appreciable increase in the percentage of gravid females. The addition of portions of the onion plant to the baits, as already stated in this paper, increases the total number of female flies caught and thus should increase the total number of gravid females destroyed.

The increase in number of Onion Maggot flies attracted to the baits due to the addition of crushed onion leaves of crushes onion bulbs.

TABLE 5.—The Increase in Number of Onion Maggot Flies Attracted to the Baits due to the Addition of Crushed Onion Leaves or Crushed Onion Bulbs.

Materials Used	No. of Flies Attracted				Per Cent	
	Expt.	Traps	Checks		Expt.	Traps
	Male	Female	Male	Female	Male	Female
Sodium Arsenite	12	49	38	84	31.6	58.3
Sodium Cyanide	17	20	38	84	44.7	23.8
Crushed Onion Leaves and Water	13	44	96	185	13.5	24.0
Crushed Onion Leaves and Molasses	63	148	38	84	165.8	176.2
Crushed Onion Bulbs and Water	30	70	96	183	31.2	38.2
Crushed Onion Bulbs and Molasses	64	93	38	84	168.4	110.7

TABLE 6.—The Percentage of Gravid Females to Spent Females Attracted to the Baits.

DATE	Sodium Cyanide				Sodium Arsenite				Molasses and water			
	No. of Flies examined	Spent Females	Under 20 eggs present	Over 20 eggs present	No. of Flies examined	Spent Females	Under 20 eggs present	Over 20 eggs present	No. of Flies examined	Spent Females	Under 20 eggs present	Over 20 eggs present
Aug. 3.....	10	10.0%	40.0%	50.0%	9	11.2%	0.0%	88.8%	5	20.0%	20.0%	60.0%
Aug. 9.....	8	25.0%	25.0%	50.0%	7	14.3%	28.6%	57.1%	15	33.4%	0.0%	66.6%
Aug. 11.....	7	14.2%	42.9%	42.9%	10	30.0%	10.0%	60.0%	12	16.6%	8.4%	75.0%
Aug. 14.....	6	0.0%	16.7%	83.3%	4	0.0%	25.0%	75.0%	6	33.4%	0.0%	66.6%
Aug. 17.....	6	16.7%	16.7%	66.6%	7	0.0%	14.3%	85.7%	11	9.1%	18.2%	72.7%
Aug. 19.....	10	0.0%	10.0%	90.0%	7	14.3%	14.3%	71.4%	8	0.0%	25.0%	75.0%
Aug. 25.....	5	20.0%	20.0%	60.0%	3	33.4%	0.0%	66.6%	3	33.4%	0.0%	66.6%
Aug. 29.....	5	20.0%	40.0%	40.0%	4	0.0%	50.0%	50.0%	7	42.9%	0.0%	57.1%
Sept. 2.....	3	0.0%	0.0%	100.0%	2	0.0%	0.0%	100.0%	10	10.0%	10.0%	80.0%
Sept. 7.....	9	0.0%	0.0%	100.0%	4	0.0%	25.0%	75.0%	12	0.0%	8.3%	91.7%
Sept. 15.....	6	16.7%	16.7%	66.6%	9	11.2%	0.0%	88.8%	8	37.5%	12.5%	50.0%
Sept. 17.....	6	16.7%	0.0%	83.3%	7	0.0%	0.0%	100.0%	11	8.3%	0.0%	91.7%
Aver. %..	81	11.6%	19.0%	69.4%	73	9.5%	13.9%	76.6%	108	20.4%	8.5%	71.1%

Total number of flies examined to give the above results: 262.

TABLE 7.—The Percentage of Gravid to Spent Females attracted to Baits Containing Portions of the Onion Plant.

Date	Molasses and Onion Leaves				Molasses and Onion Bulbs			
	No. of Flies examined	Spent Females	Under 20 eggs present	Over 20 eggs present	No. of Flies examined	Spent Females	Under 20 eggs present	Over 20 eggs present
Sept. 11	.....	.....	.....	.....	6	16.7%	0%	83.3%
Sept. 15	15	13.3%	6.7%	80%	15	33.3%	6.7%	60.6%
Sept. 17	15	6.7%	6.7%	86.6%	15	6.7%	13.3%	80.8%
Aver. %	.....	10%	6.7%	83.3%	.....	18.9%	6.6%	74.5%

15.—FIELD EXPERIMENTS OF 1926 AND 1927.

The field experiments of 1925, to determine the chemotropic responses of the onion maggot adult and dipterous flies in general, were continued in 1926. Many of the mixtures used in 1925 were discarded as not warranting further experimentation and only those that held out the best promise were selected for continued work.

One of the most satisfactory features of the work of 1926, it will be noted, was the extent of the data obtained. As only the best baits were selected during this year this would be expected, but the figures are such that one is well justified in presuming that the relative merits of the different baits used are definitely indicated. During the months of July and August nearly 89,000 flies were captured, sorted, and counted. These represent the captures from five cages run during this period. Minnesota fly traps, placed over the dishes containing the baits, were employed in the same manner as that described in #14 of this report. The flies were gathered daily.

During the month of July all the baits used had molasses as the attracting principle. A molasses solution, without poison, was run throughout the summer as a check. It will be noted that through both July and August no bait gave as big a catch of flies as that of the molasses solution. Every poison appeared to decrease, to some extent at least, the attractive qualities of the molasses solution.

The figures given of the percentage of Diptera found dead in the traps when collected undoubtedly give some indication of the relative toxicity of the various baits but at the same time there is very obviously a distinct correlation between the size of the daily catch and the number of dead found. Thus the check bait, in which there was no poison, shows the second greatest percentage of mortality, and— the biggest catch. As the size of the catch increased the

chances of physical injury to the flies increased proportionately. However, it will be noted that the sodium arsenite bait, with a lower catch, showed markedly greater toxicity than that of any other bait employed.

As recorded for the work of 1925, there seems to be a distinct correlation between the catch of Onion maggot flies and of total Diptera. One increases or decreases in relative proportion to the other.

The sodium cyanide-molasses bait, found to be the best bait in 1925, was discontinued during August 1926. Glucose, found in cane molasses, was proved to be a perfect antidote of sodium cyanide. (36).

During the month of August a granulated sugar solution was checked against the regular cane molasses solution. The molasses solution still continued to prove itself the best attractant. Sodium cyanide, in a granulated sugar solution (no glucose), gave a slightly greater catch than the sugar check and proved quite toxic.

The total catch of flies during August was very much less than during the month of July.

TABLE 8.—Composition of Various Baits used in Cage Experiments in 1926.

1.—*Check, molasses.*

Molasses	1 pint.
Water	1 gal.

2.—*Sodium arsenite.*

Sodium arsenite	¼ oz.
Molasses	1 pint.
Water	1 gal.

3. *Sodium cyanide.*

Sodium cyanide	¼ oz.
Molasses	1 pint.
Water	1 gal.

4. *Sodium fluoride.*

Sodium fluoride	¼ oz.
Molasses	1 pint.
Water	1 gal.

5. *Ferric chloride.*

Ferric chloride	¼ oz.
Molasses	1 pint.
Water	1 gal.

6. *Granulated sugar check.*

Gran., sugar and water to same sp. gravity as molasses check mixture.

7. *Sodium cyanide, sugar.*

Sodium cyanide	¼ oz.
Gran. sugar and water (same strenghth as No 6).	1 gal.

TABLE 9.—Summarized Results of Cage Experiments 1926.

Material used	Total catch of Diptera	% Diptera dead	Onion	Maggot	Other Diptera	Other Insects
			males	females		
Month of July.						
Check, molasses (1)	22418	76.7	53	97	22268	186
Sod. arsenite (2)	6471	80.9	5	58	6408	28
Sod. cyanide (3)	12200	52.7	55	81	12064	63
Sod. fluoride (4)	7989	63.2	18	101	7870	184
Ferric chloride (5)	14272	73.9	43	140	14089	202
Month of August.						
Check, molasses (1)	6636	69.0	48	102	6486	177
Check, sugar (6)	2916	46.5	13	46	2857	74
Sod. arsenite (2)	3140	76.7	19	59	3062	95
Sod. cyn. sugar (7)	3200	47.2	13	53	3134	108
Aug. 1st to 15th.						
Sod. fluoride (4)	4540	66.0	15	39	4486	104
Ferric chloride (5)	4619	74.5	11	35	4573	97
	88401		293	811	87297	1318

TABLE 10.—Comparison of Results of Cage Experiments 1926.

BAIT	Average Total Diptera per day	Average Total O M. flies per day	% Diptera dead when collected
Month of July.			
Check, molasses solution	896.7	6.0	76.7
Sodium arsenite and molasses solution	269.6	2.6	80.9
Sodium cyanide and molasses solution	451.8	5.1	52.7
Sodium fluoride and molasses solution	295.9	4.4	63.2
Ferric chloride and molasses solution	529.3	6.8	73.9
Month of August.			
Check, molasses solution	214.7	4.8	69.0
Check, Gran. sugar solution	100.6	2.0	46.5
Sodium arsenite and molasses solution	104.7	2.6	76.7
Sodium cyanide and sugar solution	110.3	2.3	47.2

In view of the favorable results attending the use of Bordeaux-oil emulsion in Illinois by Flint and Compton (35), it was decided to try out a spray of this nature in the Montreal district in order to ascertain the suitability of such a remedy in this locality. Spraying experiments were carried out on the College onion plots and on the farm of Mr. J. McEvoy's, Rosemount, Montreal.

A boiled lubricating oil emulsion was used, in the work mentioned above, at the rate of 2% in a 4-4-50 Bordeaux mixture. The oil emulsion was prepared as follows;

Light lubricating oil	2 gals.
Water	1 gal.
Resin-soda emulsifier	1 pint.

This was heated to boiling point, removed from the fire, and then pumped back and forth from one vessel to another until emulsified. Stock Bordeaux mixture was prepared in the usual way and the oil emulsion poured into the required quantity of stock Bordeaux. This was then agitated well and the requisite amount of water added.

The resin-soda emulsifier mentioned above was prepared as follows;

Resin	1½ lbs.
Caustic soda	1½ ozs.
Washing soda	5½ ozs.
Water	1 gal.

The above was heated until just about boiling and the solution clear. This may be made up in bulk and stored, care being taken however to stir well before using.

Five applications one week apart, at the rate of 120 gallons per acre, were planned; the first to be made when the seedling onions were about two or three inches above the ground. Unfortunately owing to some difficulty in getting the necessary materials delivered the first spray was omitted. Spraying was done with a compressed air spray tank, carried on the back. This would not be suitable for regular spraying as it is of course altogether too laborsome. All parts of the exposed surfaces of the onion plants were covered with the spray, with particular attention being paid to the lower portions and soil adjacent to the bulbs. At the rate of 120 gallons per acre the following materials are required for five applications;

Copper sulphate	48 lbs.
Quick lime	48 lbs.
Lubricating oil	12 gals.
Resin-soda	6 pints.

The adhering qualities of this spray were only fair but onion foliage is particularly difficult in this respect, as far as aqueous or semi-aqueous solutions

are concerned. The presence of oil in the spray improve, the spreading qualities of the spray slightly but not nearly to the extent that could be wished. Soil particles take up the spray very readily.

On examining the sprayed plots a day or so after spraying, particularly in hot weather, it was found that considerable "spotting" of the foliage was noticeable. The spray tends to gather in small droplets, of varying size, on the foliage. These concentrations of spray material apparently result in injury to the chlorophyll of the cells beneath them. This spotting may range all the way from distinct injury to the underlying tissues to temporary loss of color only. In no case observed did the spray result in the death of the plant.

Definite data on the effectiveness of the spray against Onion maggot attack were not secured as both sprayed and unsprayed portions of the onion field were practically exempt from injury of this nature. Onions had not been grown on this field the year previously and it was located on that part of the farm that was highest in organic matter.

The onions of the sprayed plot were markedly larger in size than the others in the same field. In addition those in the sprayed plot stood up about two weeks longer than all the rest. The effect of the spraying on the onion plant was most satisfactory.

16.—NATURAL ENEMIES.

The following natural enemies have been recorded as preying on the onion maggot. The majority of these were first determined by Armstrong in 1924.

Parasites.

Aleochara verna Say. (from pupa).
Xantholinus obscurus Er. (from pupæ).
Spalangia muscidarum Rich. (accidental?) (from pupa).
Cothonaspis gillettei Walsh (Cynipid).
Baryodma ontarionis Casey (pupa).
Aphaereta muscae Ashm. (pupa).

Predators.

Atheta sordida.
Atheta sp.
Aleochara bipustulata L.
Aleochara sp.
Philonthus sp. (probably *discoideus*).
Lathrobium collare Ev.
Quidius peregrinus Grav.
Oxytelus rugosus.
Baryodma ontarionis Casey.

Carabidae collected from onion fields where the maggot was working (Armstrong)
Harpalus pennsylvanicus Say. (by far most common).
Pœcilus lucublandis Say. (very common).
Anadaptus baltimorensis Say.
Bradytus apricarius Payk.
Harpalus viridiœneus Beaut.
Platynus placidus Say.
Bradytus latior Kby.
Bembidium quardimaculata Say.
Agonoderus pallipes Fab.

It will be noted that it is apparently only in the pupal stage that the onion maggot is parasitized. Egg, larval or adult parasites have not been observed.

Predators attack the onion maggot during the egg, larval and pupal stages. No doubt the adults have their own quota of predators to contend with but such activities are not so readily observed. It is doubtful if the adults have any but general predators active against them.

Both as parasites and predators the Staphylinid beetles are by far the most important natural enemies of the onion maggot. The various species of Carabidæ undoubtedly contribute materially to a decrease in numbers of this insect as well.

17.—SUMMARY.

1. The onion maggot (*Hylemyia antiqua*) has been known in Europe for many years. It is thought to have been brought over to North America in shipments of onion bulbs from Sweden, Holland, Denmark and England. It has become widely distributed in the United States and is now prevalent in Canada from coast to coast.

2. In Canada the onion maggot is undoubtedly the most destructive insect infesting the onion plant. In the province of Quebec it occurs wherever onions are grown to any extent and every year the onion crop is depleted to some extent and from time to time very severe losses occur.

3. Several species of Diptera have been recorded as feeding on the onion bulb in Quebec, but of these *Hylemyia antiqua* is apparently the only one that attacks a healthy onion.

4. Descriptions of the onion maggot in egg, larval, pupal and adult stages are given.

5. There are two full generations of the onion maggot yearly and a partial third. While there is considerable overlapping of broods egg laying is greatest during June and August. The onion maggot overwinters in the pupæ stage and the first of the flies emerge from the middle to the end of May (Quebec). The maximum emergence of the first brood is around the second week in June. The average preoviposition period is about 11-12 days, varying with climatic conditions.

6. Injury from the onion maggot is first detected by the dropping of the seedling onions which usually occurs about the middle of June. This is caused by the burrowing of the maggots into the bulbs. Young injured plants usually die, while rot frequently results in older onions. It is the spring brood which causes by far the greater damage and in consequence control efforts are usually largely directed against this generation.

7. There appears to be very little difference in the relative resistant powers of different varieties of onions to maggot attack, so far as observed in this locality.

8. Cool weather lenghtens the incubation period of the eggs while warm weather tends to shorten same. Sunlight and dryness play an important role in preventing development within the egg. Excessive moisture does not seem to have any detrimental effect upon the egg.

9. The larvæ of *Hylemyia antiqua* apparently restricts its feeding activities to onions, garlic and leek; onions being by far the commonest host.

10. The eggs are usually laid within an inch or so of the onion plant. From experiments this appears to be the limit to which a newly hatched larva can migrate. Larvæ that have attained partial growth can and will migrate considerable distances to a more suitable environment. The tendency of migration is away from the source of light. One heavily infested plant may be the source of infestation to a number of plants in its immediate vicinity, particularly if the plants are close together.

11. Flies of the summer brood emerged from the pupæ in 14-16 days. Only a small percentage took longer than 16 days and nearly half 14 days. The pupal mortality was 6.5%.

12. Pupæ are not able to withstand excessive drying of the soil. About 4% of moisture seems to be most favorable, while a high percentage of emergence was obtained up to 16%. Soil that was practically saturated (32%) gave an emergence of 53.3%.

13. Extremes of temperature will retard pupal development.

14. The onion flies feed on the blooms of many of our flowering plants. Of these the dandelion is the most important, at least in Quebec.

15. There is a direct relation between the prevalence of the dandelion blooms and the generations of the onion flies.

16. Sunlight and warmth are essential to mating and oviposition.

17. Trap and volunteer onions are invariably the most heavily infested plants in the field as long as they are available. Onion plants whose leaves branch out near the surface of the soil prove most attractive for oviposition. Injured or diseased plants are also preferred.

18. The act and place of oviposition is described.

19. The pH of a soil does not appear to have any important influence on the degree of maggot infestation, within such limits as would render the soil still suitable for the cultivation of onions.

20. Physical examinations of maggot infested and uninfested soils did not yield any proof for the belief that a slight predominance of any of the soil separates, gravel, fine gravel, coarse sand, medium sand, fine sand, very fine sand, slit, or clay, such as might be found within the ranges of soil suitable for the growth of onions, would be influential in rendering the soil more liable to onion maggot infestation.

21. The percentage of organic matter in the upper layers of the soil is frequently closely related to the degree of infestation. Conditions may be rendered more favorable for the development of their natural enemies.

22. Control measures have been largely directed against the adult female fly. The onion maggot is most open to attack in the adult stage. A historical review of control measures is given. The Sander's "poison bait", and the "trap crop" methods of control have proved most successful in the past.

23. A long series of tests was made of numerous substances to find which might prove of greatest value as attractants, as poisons or combination of both, of the onion flies. These baits were tried out under field conditions and the visiting insects captured through the use of Minnesota fly traps. In 1925 fifty-five different baits were tried over periods of varying length. The more successful baits were caried over for further trial during the summer of 1926.

24. The catches of all kinds of Diptera always bore a close relation to the relative catches of onion maggot flies. During 1925, the number of miscellaneous flies taken approximated nearly 20,000 individuals, of these 2905 were onion maggot flies of which 1767 were females and 1138 were males.

25. The best baits of 1925 were the sodium arsenite-molasses, ferric chloride-molasses, sodium fluoride-molasses, and sodium cyanide-molasses. A molasses-water check always gave a high catch.

26. Of the female flies attracted to the more successful baits those flies having over twenty eggs present were more numerous than the spent females or those having under twenty eggs.

27. Portions of the onion plant appear to increase the attractiveness of the baits.

28. Field experiments to determine the chemotropic responses of the onion fly and adult Diptera in general, were continued in 1926. Only the best baits were selected during this year and during the months of July and August nearly 89,000 flies were captured, sorted and counted from five cages run during this period. The flies were gathered daily. The role played by glucose, found in cane molasses, as an antidote of sodium cyanide being proved by the senior author, this bait was discontinued and one with granulated sugar as the attractive principle substituted.

29. The sodium arsenite-molasses, ferric chloride-molasses and sodium fluoride-molasses baits gave the best results. The catches obtained at the molasses-water check were greater than any of the above. A molasses solution is considerably more attractive to the flies than a granulated sugar solution.

30. A Bordeaux oil emulsion spray was tried out during the summer of 1927. Larger and cleaner onion bulbs were obtained from the sprayed plots than from the unsprayed portions.

31. Staphylinid and Carabid beetles are the most important natural enemies of the onion maggot. They are very frequently important factors in checking the natural increase of this insect.

18.—REFERENCES.

1. 1840 Dewdney, Geo., Jour. Royal Soc. England, Vol. 1.
2. 1841 Harris, T. W., A Report on the Insects of Massachusetts injurious to Vegetation, pp. 415-416.
3. 1862 Harris, T. W., Insects Injurious to Vegetation, pp. 617.
4. 1866 Fitch, A., Eleventh Report on Noxious, Beneficial and other insects of New York, pp. 31-38.
5. 1875 Couper, Wm., Ann. Rept. Ent. Soc. of Ont., pp. 333.
6. 1879 Ormerod, E. A., Notes of Observations of Injurious Insects, Rept. for 1879, pp. 12-13.
7. 1882 Lintner, J. A., New York State Ent. Ann. Rept. No 1., pp. 172-181.
8. 1883 Ormerod, E. A. Report of Observations of Injurious Insects during the year 1882, pp. 78-80.
9. 1885 Fletcher, J., Report of the Entomologist, Dom. Dept. Agric. pp. 18.
10. 1891 Fernald, C. H., Report on Insects, Hatch Expt. Sta., Mass., Bul. No. 12, pp. 17-19.
11. 1891 Fletcher, J., Recommendations for the Prevention of Damage by Some Common Insects of the Farm the Orchard and the Garden, Can. Dept. Agric. Bul. No. 11, pp. 29.
12. 1893 Smith, J. B. Rept. of Ent. Dept. New Jersey, pp. 441.
13. 1894 Slingerland, M. V., The Cabbage Root Maggot with notes on the Onion Maggot and Allied Insects, New York (Cornell) Agric. Expt. Sta. Bull, No. 78, pp. 495-496.
14. 1904 Fletcher, J., Report of the Entomologist, Rept. of Dom. Expt. Farm, pp. 226.
15. 1907 Smith, J. B., and Dickerson, E. L., New Jersey Agric. Expt. Sta. Bul. No. 200.
16. 1909 Swaine, J. M., 2nd Ann. Rept. Quebec Soc. for the Protection of Plants, pp. 53
17. 1912 Chittenden, F. H., Insects Injurious to the Onion Crop, U. S. Yearbook, pp. 327-332.
18. 1913 Sanders, J. G., Wisconsin Expt. Sta. Bul. No. 240, pp. 45.
19. 1914 Severin, H. H. P., Can. Entomologist, Vol. 46, pp. 312-313.
20. 1915 Severin, H. H. P., and Severin, H. C., Life History, Natural Enemies and the Poisoned Bait Spray as a Method of Control of the Imported Onion Fly, Jour, Econ. Ent., Vol. 8, No 3, pp. 347-348.
21. 1916 Chittenden, F.H., The Distribution of the Imported Cabbage and Onion Maggots, Jour, Econ. Ent., Vol. 9, Dec. 9, pp. 571.
22. 1916 Sanders, J. G., Insects Notes for 1916, Biennial Rept. Wisconsin, Dept. of Agriculture Bul, No. 10, pp. 51.
23. 1917 Gibson, Arthur, Ann. Rept. Ento. Soc. of Ont., pp. 30-33.
24. 1918 Howard, Neale, F., Poisoned Bait for the Onion Maggot, Jour. Econ. Ent. Vol. 11, pp. 82-84.
25. 1919 Fernald, H. T., and Bourne A. I., 31st Ann. Rept Mass, Agric. Expt, Sta., Jan. 1919
26. 1921 Lochhead, W. and Tawse, W. J., 14th Ann. Rept, Quebec Soc. for the Protection of Plants, pp. 29-33.
27. 1921 Treherne, R. C. and Ruhman, M. H., 52nd Ann. Rept. Ent. Soc. Ont., pp. 29-33.
28. 1922 Eyer, John R., The Bionomics and Control of the Onion Maggot, Penn. State College Agric. Expt. Sta. Bul. No. 170, pp. 11.
29. 1922 Smith, K. M., A study of the Life History of the Onion Fly, Ann. App. Biol., Vol. IX, No. 3-4, pp. 177-183.
30. 1923 Armstrong, T., Onion Maggot Studies in the District of Montreal, Que., 54th Ann. Rept. Ent. Soc. Ont., pp. 42-44.
31. 1923 Smith, K. M., Review App. Ent., Series A., Vol. 11, pp. 126-127.
32. 1923 Winston, J. R., Bowman, J. J., and Yothers, W. W., Bordeaux-oil Emulsion, U.S.D. A., Depart. Bull. No. 1178.
33. 1925 Compton Charles C., Insects Injurious to Onions, Illinois Agric. College and Expt. Sta. Circ., No. 297, June, 1925.
34. 1925 Smith, K. M., Ann. App. Biol., XII, No. 1, pp. 77-92, Feb. 1925.

35. 1925 Flint, W. P. and Compton, C. C., A New Method for Controlling the Onion Maggot. Jour. of Econ. Ent. Vol. 18, No 1, Feb., 1925, pp. 111-115.
36. 1927 Baker, Alex D. and DeLong, W. A., Glucose as an Antagonist. Science Vol. LXVI, No. 1715, Nov. 11, 1927, pp. 457-458.
37. 1927 Baker, Alex. D., Habits of the Onion Maggot, Flies, (*Hylemyia antiqua*, 58th Rep. Ent. Soc. of Ont.

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